MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXII. *February* 9, 1872. No. 4

WILLIAM LASSELL, Esq., F.R.S., President, in the Chair.

Edward Henry Cooper, Esq., Markree Castle, Ireland;
J. Kennedy Esdaile, Esq., New University Club;
Isaac Engelson, Esq., Paris;
Capt. John Herschel, F.R.S., India;
D. Lindsay Lowson, Esq., 164 Kennington Road;
John Martin, Esq., 72 Adelaide Square, South Shields;
Capt. H. O'Reilly, Queensland;
E. Roberts, Esq., 3 Union Place, Blackheath Road; and
George Wall, Esq., Colombo, Ceylon,

were balloted for and duly elected Fellows of the Society.

Report of the Council to the Fifty-second Annual General Meeting of the Society.

Progress and present state of the Society:—

	Compounders.	Annual Contributors.	Non-residents.	Patroness, and Honorary.	Total Fellows.	Associates.	Grand Total.
December 31, 1870	192	305	10	3	510	44	554
Error in last Report	−2	...	...	...	...	...	...
Since elected ...	+6	+10	...	...	...	...	...
Deceased	−6	−8	−1	...	...	...	...
Removals	+2	−2	...	...	...	...	...
Resigned	...	−5	...	...	...	...	...
Expelled for non-payment of arrears, &c. ...	...	−6	...	...	...	...	...
Dec. 31, 1871 ...	192	304	9	3	508	44	552

Mr. Whitbread's Account as Treasurer of the Roy

RECEIPTS.

1871.		£	s.	d.	£	s.
	Balance of last year's account				270	1
Jan. 6	By Dividend on £3400 Consols	50	3	0		
Apr. 6	By ditto on £5000 New 3 per Cents ...	73	15	0		
July 6	By ditto on £3400 Consols	49	14	6		
Oct. 6	By ditto on £5200 New 3 per Cents ...	76	1	0		
					249	13
	Received for arrears of contributions £210 11					
	192 annual contributions ... 401 2	611	13	0		
	Admission-fees	62	18	0		
	First years' contributions	39	16	0		
					714	7
	7 compositions	...		...	147	0
	Sale of publications:—					
	At the Rooms of the Society	5	11	6		
	By Messrs. Williams and Norgate ...	23	11	0		
					29	2
					£1410	4

Astronomical Society, from January 1 to December 31, 1871.

EXPENDITURE.

	£ s. d.	£ s. d.
Salaries:—		
Editor of Monthly Notices	60 0 0	
Assistant Secretary	130 0 0	
Commission on Collecting	36 0 0	
		226 0 0
Taxes:—		
Land and Assessed	7 0 9	
Income	1 17 8	
Poor Rate	11 17 0	
Other Parish Rates	5 9 8	
		26 5 1
Bills:—		
Strangeways, printer	220 6 3	
Rumfitt, bookbinder	17 12 7	
Malby, engraver	6 15 0	
Metcalf, ditto	12 5 0	
Insurance	7 15 6	
Mr. Williams, in aid of printing Chinese Observations of Comets	50 0 0	
Grant in aid of Eclipse Expedition, 1870	250 0 0	
		564 14 4
Miscellaneous items:—		
House expenses	25 1 10	
Stamps and postages	33 19 10	
Books and parcels	7 3 0	
Expenses of evening meetings	13 13 0	
Waiters attending meetings	3 17 0	
Coals and wood	12 0 0	
Gas	8 2 11	
Repairs	1 8 6	
Sundries	23 19 1	
		129 5 2
Mrs. Jackson Gwilt's annuity, 1 year ...		8 16 0
		955 0 7
Investment:—		
Purchase of £200 New 3 per Cents, 91⅛		183 10 0
		1138 10 7
Balance at Banker's		271 13 7
		£1410 4 2

Examined and found correct, Jan. 25, 1872,

(Signed) H. Perigal, W. T. Lynn, W. B. Gibbs, } *Auditors.*

Assets and Present Property of the Society, January 1, 1872:—

	£	s.	d.	£	s.	d.
Balance at Banker's	...		...	271	13	7
3 Contributions of 7 years' standing ...	44	2	0			
5 ,, 6 ,, ...	63	0	0			
12 ,, 5 ,, ...	126	0	0			
2 ,, 4 ,, ...	33	12	0			
9 ,, 3 ,, ...	56	14	0			
9 ,, 2 ,, ...	37	16	0			
51 ,, 1 ,, ...	107	2	0			
Balances of several Accounts	19	2	0			
				487	8	0
Due for Publications	...		...	17	10	0
£5200 New 3 Per Cents (including Mrs. Jackson Gwilt's Gift, £300).						
£3400 Consols, including the Lee Fund (£100) and Turnor Fund (£500).						
Unsold Publications of the Society.						
Various astronomical instruments, books, prints, &c.						
Balance of Turnor Fund (included in Treasurer's Account)				167	12	9

Stock of volumes of the *Memoirs*:—

Vol.	Total.	Vol.	Total.	Vol.	Total.
I. Part 1	11	XIII.	198	XXVII.	456
I. Part 2	51	XIV.	390	XXVIII.	416
II. Part 1	69	XV.	173	XXIX.	448
II. Part 2	33	XVI.	198	XXX.	297
III. Part 1	85	XVII.	181	XXXI.	173
III. Part 2	104	XVIII.	176	XXXII.	204
IV. Part 1	102	XIX.	183	XXXIII.	207
IV. Part 2	104	XX.	179	XXXIV.	193
V.	124	XXI. Part 1	216	XXXV.	167
VI.	150	XXI. Part 2	100	XXXVI. (with M. N.)	250
VII.	175	XXI. (together).	89	XXXVI. (without)	35
VIII.	161	XXII.	182	XXXVII. Part 1	353
IX.	164	XXIII.	176	XXXVII. Part 2	402
X.	174	XXIV.	182	XXXVIII.	438
XI.	184	XXV.	196	XXXIX. Part 1	511
XII.	189	XXVI.	200		

The instruments belonging to the Society are as follows:—

The *Harrison* clock,
The *Owen* portable circle,
The *Beaufoy* circle,
The *Beaufoy* transit,
The *Herschelian* 7-foot telescope,
The *Greig* universal instrument,
The *Smeaton* equatoreal,
The *Cavendish* apparatus,
The 7-foot Gregorian telescope (late Mr. Shearman's),
The Variation transit (late Mr. Shearman's),
The Universal quadrant by Abraham Sharp,
The *Fuller* theodolite,
The Standard scale,
The *Beaufoy* clock, No. 1,
The *Beaufoy* clock, No. 2,
The *Wollaston* telescope,
The *Lee* circle,
The *Sharpe* reflecting circle,
The *Brisbane* circle,
The *Baker* universal equatoreal,
The *Reade* transit.

The *Sheepshanks'* collection of instruments, viz.,—

1. 30-inch transit, by Simms, with level and two iron stands.

2. 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumbline; portable clamping foot and tripod stand.

3. $4\frac{6}{10}$ achromatic telescope, about 5 feet 6 inches focal length; finder, rack motion; double-image micrometer; object-glass micrometer; two other micrometers; one terrestrial and ten astronomical eyepieces, applied by means of two adapters, with equatorial stand and clock movement.

4. $3\frac{1}{4}$-inch achromatic telescope, with equatorial stand; double-image micrometer; one terrestrial and three astronomical eyepieces.

5. $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.

6. $2\frac{3}{4}$ achromatic telescope, about 30 inches focus; one terrestrial and four astronomical eyepieces.

7. 2-foot navy telescope.

8. 45-inch transit instrument, with iron stand, and also Y's for fixing to stone piers; two axis levels.

9. Repeating theodolite, by Ertel, with folding tripod stand.

10. 8-inch pillar-sextant, divided on platinum, with counterpoise stand and horizon roof.

11. Portable zenith instrument, with detached micrometer and eyepiece.

12. 18-inch Borda's repeating circle, by Troughton.

13. 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms.

14. A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, with extra pair of parallel plates; tripod staff, in which the telescope tube is packed; repeating table; level collimator, with micrometer eyepiece; and Troughton's levelling staff.

15. Level collimator, plain diaphragm.

16. 10-inch reflecting circle, by Troughton, with counterpoise stand; artificial horizon, with metallic roof; two tripod stands, one with table for artificial horizon.

17. Hassler's reflecting circle, by Troughton, with counterpoise stand.

18. 6-inch reflecting circle, by Troughton, with two counterpoise stands, one with artificial horizon.

19. 5-inch reflecting circle, by Lenoir.

20. Reflecting circle, by Jecker, of Paris.

21. Box sextant and 3-inch plane artificial horizon.

22. Prismatic compass.

23. Mountain barometer.

24. Prismatic compass.

25. 5-inch compass.

26. Dipping needle.

27. Intensity needle.

28. Ditto ditto.

29. Box of magnetic apparatus.

30. Hassler's reflecting circle, with artificial horizon roof.

31. Box sextant and $2\frac{1}{4}$-inch glass plane artificial horizon.

32. Plane speculum artificial horizon and stand.

33. $2\frac{1}{2}$-inch circular level horizon, by Dollond.

34. Artificial horizon roof and trough.

35. Set of drawing instruments, consisting of 6-inch circular protractor; common ditto; 2-foot plotting scale; two beam compasses and small T square.

36. A pentagraph.

37. A noddy.

38. A small Galilean telescope, with the object lens of rock-crystal.

39. Six levels, various.

40. 18-inch celestial globe.

41. Varley stand for telescope.

42. Thermometer.

43. Telescope, with the object-glass of rock crystal.

To these must be added the following instruments which had been employed in the Observations of the Total Solar Eclipse of 1870, and which, by a resolution of the joint Eclipse Committee of 1870, were transferred to the Royal Astronomical Society:—

Portable equatoreal stand,
Portable altazimuth tripod,
Four polarimeters,
Two Biquartz and Nicol's prisms,
Registering spectroscope, without prism,
Camera and chemicals, in box,
Two five-prism spectroscopes,
Cradle for telescope,
Eight-inch reflector and stand, with seven prisms,
Spectroscope,
A small box, containing—
Three square-headed Nicol's prisms,
Two Babinet's compensators,
Two double-image prisms,
Three Savarts,
One positive eye-piece, with Nicol's prism,
One dark wedge.

These are now in the apartments of the Society, with the exception of the following, which are lent, during the pleasure of the Council, to the several parties under mentioned, viz.:—

The *Fuller* theodolite, to the Director of the Sydney Observatory.
The *Beaufoy* transit, to the Observatory, Kingston, Canada.

The *Sheepshanks* instrument, No. 1, to Mr. Lassell.
Ditto ditto No. 2, to Mr. Huggins.
Ditto ditto No. 3, to Mr. Proctor.
Ditto ditto No. 4, to Rev. C. Lowndes.
Ditto ditto No. 5, to Mr. Birt.
Ditto ditto No. 6, to Rev. J. Cape.
Ditto ditto No. 8, to Rev. C. Pritchard.
Ditto ditto No. 9, to the Director of the Sydney Observatory.
Ditto ditto No. 41, to Rev. C. Pritchard.
Ditto ditto No. 43, to Mr. Huggins.
The 6-inch circular protractor, to Mr. Birt.

Lent on account of the Eclipse Expedition:—

Two polarimeters. Col. Tennant.
One ditto. Mr. Ranyard.
One ditto. B. A. Eclipse Committee.
One Biquartz and Nicol's prism. Col. Tennant.
One ditto ditto. Mr. Ranyard.
Registering spectroscope, no prism. Col. Tennant.
Camera and chemicals, in box. B. A. Eclipse Committee.
One five-prism spectroscope. B. A. Eclipse Committee.
One ditto. Mr. Lockyer.

The Gold Medal.

The Council have awarded the Gold Medal to Signor Schiaparelli for his researches on the connexion between the orbits of comets and meteors. At the close of the ordinary business the President will explain to the Society the reasons which guided the Council in awarding the Medal to Signor Schiaparelli.

New Bye-law relating to the Award of the Medal.

At a Special General Meeting of the Society, held after the business of the Ordinary Meeting in June was concluded, the following Bye-law was submitted to the Fellows, and unanimously adopted.

In Section XVI. add:—

"75*. Notwithstanding the preceding Bye-laws, in cases where two or more persons have been jointly concerned in the production of any scientific treatise, or the carrying out of any research, work, or discovery, or have been the simultaneous but independent authors of any such treatise, work, research, or discovery, the Council may, under these circumstances, receive the nomination of such two or more persons as joint recipients of the Medal, and proceed thereupon in like manner as above mentioned with respect to the names of separate persons; and should the Medal be ultimately awarded to such joint authors, workers, or discoverers, an impression of the Medal shall be provided for and given to each of such joint recipients."

The Council have for some years past felt the importance of possessing the power to award a joint Medal when original researches have been performed by two or more persons, either when working conjointly, or when independent investigations on the same subject have been made. They are glad therefore to find that this feeling is also shared by the Fellows generally.

Printed Transactions of the Society.

Memoirs.

Part I. of Volume XXXIX. of the *Memoirs* has been published since the last Report. This Part contains a memoir by Professor Cayley "On the Graphical Construction of a Solar Eclipse," with an illustrative plate.

Many of the communications now printed in the *Monthly Notices* would, in former years, have been included in the *Memoirs*. This alteration in the manner of printing is generally both advantageous to the Author and the Fellows by the more rapid publication and distribution of matters of interest. A few of the subjects which have been before the Society, with others which bear upon the progress of Astronomy, are referred to in another section of the Report.

General Index to the Memoirs.

The Index to the *Monthly Notices* has been found so useful and acceptable to the Fellows, that the Council gave instructions to the Assistant-Secretary to prepare a General Index to the *Memoirs*, uniform with the Index to the *Monthly Notices*, including all the titles of Papers and the names of the authors contained in Volumes I.–XXXVIII. The work was completed by Mr. Williams during the recess, and placed in the hands of the Fellows in November last. The two Indexes thus form a complete catalogue of the numerous contributions towards the progress of our science which have been laid before the Society from its foundation to the present time.

Obituary.

The Council have to deplore the loss by death of a long list of Fellows, several of whom were distinguished astronomers and former officers of the Society. Sir John Herschel and Mr. Babbage were the last survivors of the small band of scientific men who met together at the Freemasons' Tavern on January 12th, 1820, "to take into consideration the propriety and expediency of establishing a Society for the encouragement and promotion of astronomy," a meeting which resulted in the foundation of the Royal Astronomical Society. The following list contains the names of the deceased Fellows:—

Fellows:—Charles Babbage, Esq., F.R.S.
Capt. J. Palladio Basevi, R.E.
Rev. A. W. Deey.
Augustus De Morgan, Esq.
Lt.-Gen. Sir W. T. Denison, K.C.B., F.R.S.
Earl of Dunraven, F.R.S.
Capt. R. W. H. Hardy, R.N.
Sir J. F. W. Herschel, Bart., F.R.S.
Sir A. Lang.
Sir Roderick I. Murchison, Bart, K.C.B., F.R.S.
Admiral Sir William Ramsay, K.C.B.
William Rutherford, Esq., LL.D.
Charles E. Smith, Esq.
Capt. David Smith.
Rev. William Taylor, F.R.S.
Rev. T. W. Weare.

Charles Babbage was born on St. Stephen's day, 26th December, 1792, and died on 18th October, 1871, aged nearly seventy-nine years. His parents were of good standing in the middle class. His early education, which commenced at five years, was conducted at various private schools, whence, after a

short sojourn with a private tutor, he was sent at the usual age to the University of Cambridge.

His love of investigation, which became the ruling passion of his life, was displayed when quite a child, and was first evinced by an experiment which he made in order to ascertain whether or not the Devil could really be raised in a personal form. The result, which was negative, removed a doubt which had obscured his religious belief, and his theological views seem from that time to have enjoyed undisturbed stability.

Babbage, like many men of great and original powers, made light of ancestry. Discussing the possibility that he might be descended from Tubal Cain, on the ground that he was, like himself, a great worker in iron, he pointed out that this hypothesis is shaken by the fact that to Tubal Cain is ascribed the invention of the *organ*, an instrument against which the subject of this notice, as is well known, carried on an incessant war.

It does not appear that Babbage owed either his tastes or his acquirements to external influences. Before going to Cambridge he had already, following his innate tendencies, plunged deeply into arithmetical and mathematical studies, reading such works as Humphrey Ditton's *Fluxions*, Agnesi's *Analytical Institutions*, Woodhouse's *Principles of Analytical Calculation*, Lagrange's *Théorie des Fonctions*, and the *Fluxions* of Maclaurin and of Simpson; and when he went to Cambridge the *dots* of Newton, the *d*'s of Leibnitz, and the *dashes* of Lagrange were equally familiar to him.

Discursive and unassisted studies led, as they usually do, to independent habits of thought. His acquirements lay rather outside the established system of the University, and the difficulties he necessarily encountered seem to have been difficulties to the tutors to whom he vainly resorted for their solution. His confidence in the routine of the place was shaken, and he presumed to think for himself. Turning to the works of foreign mathematicians, he was "penetrated with the superior power of the notation of Leibnitz."

But he was not alone. A society for the promotion of analysis was formed at his suggestion, amongst the first members of which stand the names of Herschel, Peacock, D'Arblay, Ryan, Robinson, and Frederick Maule. They held meetings at which papers were read and discussed. The first volume of *Transactions* published was exclusively the work of Herschel and Babbage,—the latter proposing as its title "The Principles of D-ism in opposition to the Dot-age of the University." Persisting in these revolutionary schemes, Babbage, assisted by Peacock, translated the smaller work of Lacroix. Peacock, Herschel, and Babbage, afterwards published a collection of examples with their solutions: Peacock of the applications of the differential and integral calculus, Herschel of those of the calculus of finite differences, and Babbage of the solutions of functional equations. This work, by lightening the labours of the tutors, obtained their support, and

contributed much to the introduction of the system. "In a few years," says Babbage, "the change was completely established; and thus at last the English cultivators of mathematical science, untrammelled by a limited and imperfect system of signs, entered on equal terms into competition with their Continental rivals." Babbage had previously published an essay on the Calculus of Functions, and memoirs on the same subject. The creation of this as yet insufficiently-cultivated branch of analysis may in fact be considered as due to him.

Babbage's time and thoughts at Cambridge were not wholly engrossed by mathematics,—he worked with Herschel, under Smithson Tennant, at chemistry,—nor did his various studies suffice to employ his exuberant energy,—he joined in the amusements of the place, devoting himself particularly to boating with the vigour that so conspicuously characterized him.

It was here, in 1812 or 1813, that the first idea of a calculating machine germinated in his mind,—an idea that shaped his whole life, and fixed his name for ever in the history of Science.

It is impossible in a brief notice like the present to give a detailed account of this wonderful mechanical substitution for intellectual operations. A few leading facts may however be mentioned. The first engine designed by Babbage was named by him the "Difference Engine," its object being to compute tables by the method of differences, an object attainable by means little beyond that required for performing the arithmetical operation of addition. But the performance of this apparently simple task involves the process of carrying over the tens,—and to do this by mechanical means constituted the main difficulty of the undertaking,—a difficulty the solution of which occupied even the mind of Babbage during a long series of years.

After considerable progress had been made by Babbage in the construction of the "Difference Engine," an idea of a still higher order occurred to him,—that of an "Analytical Engine,"—a machine not for mere tabulating like the Difference Engine, but for calculating out any formulæ presented to it. Its principle seems to have been based upon, if not suggested by, that of the Jacquard loom, which, as Mr. Babbage points out, "is capable of weaving any design which the imagination of man may conceive." These designs, as is well known, are reproduced in the fabric by means of perforated cards, a distinct set of cards being required for each different design. Applying this principle to the Analytical Engine, each operation required two distinct sets of perforated cards,—one appertaining to the formula to be developed, the other containing the constants belonging to the particular case of which a solution was desired. The first set of cards prepared for a given formula would at any time recalculate that formula with whatever constants were furnished to it by the other set. The engine, therefore, was quite general in its application.

Besides performing these main operations, the machine was designed to execute the following subsidiary work:—To print on

paper one or two copies of its results ; to produce a stereotype mould of the tables or results computed by it ; and to punch on blank pasteboard cards or metal plates the numerical results of any of its computations. The speed with which its work should be executed was almost as astonishing as the work itself. It would multiply fifty figures by the same number in one minute.

Such was the complexity of these marvellous engines that even their gifted inventor found it difficult to interpret to himself his own drawings. He was also embarrassed by the number of modes of producing the same action suggested by his prolific inventiveness. Nor could he rest satisfied with less than a *demonstration* that the mode selected was the best. To meet these fundamental difficulties he found it absolutely necessary first to invent a system of Mechanical Notation, such that when applied to his drawings it should give at once, by simple inspection, without any verbal description whatever, all the elements required for explaining the nature, position, object, and effect of every part of the machine depicted.

His paper, descriptive of this system, which is of universal application, "On a method of expressing by Signs the Action of Machinery," was read before the Royal Society, on the 16th of March, 1826. This memoir alone would confer celebrity on its author.

Mr. Babbage was justly proud of his system of Mechanical Notation, and was fond of performing the following feat to exhibit its powers. He would request his visitor to select one from the hundreds of drawings before him, executed perhaps ten years previously. Turning his back on the drawings, he desired his visitor to place his finger on any part of it. He then asked him a few questions as to the letters and symbols on or near that part,—whether they were upright or sloping, large or small, Arabic or Roman, and so on,—and he then, without any apparent exercise of thought and without any hesitation, described the part, its function, position, and relation to the whole. It was his opinion that this system of Notation was as indispensable to the designing of the engine as tools were to its construction.

The history of these marvels of intellect has often been told, and is sad indeed. For a full and trustworthy account of it, the reader is referred to Weld's *History of the Royal Society*. A mere outline only can be here given.

It was proposed that the Government should contribute to the construction of the "Difference Engine." The question was referred to a committee of the Royal Society, consisting of Sir H. Davy, Mr. Brande, Mr. Combe, Mr. Francis Baily, Mr. Brunel, Major Colby, Mr. Davies Gilbert, Sir John Herschel, Captain Kater, Mr. Pond (Astronomer Royal), Dr. Wollaston, and Dr. Young. This most competent tribunal reported favourably on the project, stating that "they considered Mr. Babbage as highly deserving of public encouragement in the prosecution of his arduous undertaking." Funds were accordingly provided by Govern-

ment from time to time, but being never adequate in amount, Mr. Babbage himself contributed largely to the expenses from his own resources. Time went on, the works proceeded, and the design not only grew, but became productive of new ideas. The conception of the Analytical Engine resulted. No sooner did this advance in the subject appear to its author capable of practical execution than, with characteristic candour, he felt bound to communicate it to the Government, as affecting the question whether, with such a prospect of almost boundless powers of mechanical calculation before them, they would persevere in the construction of the more limited Difference Engine. For seven years Mr. Babbage's applications to various ministers and administrations failed to elicit an answer to this simple question. At length, on 4th Nov. 1842, the answer came from Mr. Goulburn (Chancellor of the Exchequer in Sir Robert Peel's Cabinet), regretting that, on the grounds of expense, the completion of the machine must be abandoned, and offering to place at Mr. Babbage's disposal all that existed of it. This latter offer Mr. Babbage declined, feeling that he had no right to accept public property which he perhaps considered the Government had no right to bestow upon him.

It is no part of our intention here to revive the personal animosity which the whole management of these transactions naturally excited. But we may extract a lesson from them. It must be evident to any one who studies the documents connected with the case that the inconsistencies and narrowness of view apparent in them arose mainly from the fact that there was no provision in the Government for the proper consideration of such a question — no minister, no department, no official advisers, who could properly be made responsible for thoroughly investigating the matter, and for pronouncing a well-weighed decision upon it. The consequence was, that in the press of party politics, no one minister would give the requisite attention to such a matter. The advice of the Royal Society, twice given in most decided terms in favour of Mr. Babbage's proposal, not being official, was ultimately disregarded; and the pretext of expense, always ready when the object of the expenditure is not understood, was, as has often happened in similar cases before and since, turned to account.

The deficiency in our administration, which operated unfavourably in this famous case, still exists. In a country which produces, it is true, but one Babbage in an age, yet teems beyond all other countries with inventors ready to devote their genius to the public good, there exists, as yet, no public functionary charged with the examination of the thousands of inventions, and discoveries, and projects of which, with enormous advantage to the country at large, the Government might readily avail themselves. The archives of this Society are not without records of difficulties in connexion with its own branch of science, in which the want of

a minister competent to deal with astronomical undertakings requiring State aid, has been felt.

To return to the subject of this notice. Mr. Babbage states that the following sums were spent upon the Difference Engine: —by the Government, about 17,000*l.*; by himself, upwards of 20,000*l.* The part completed was deposited in the Museum of King's College. Thence it was removed, through the great personal exertions of the late Mr. Gravatt, C.E., to the International Exhibition of 1862; after the closing of which it was transferred to the South Kensington Museum, where it now remains.

Babbage now turned his mind to the Analytical Engine; but experience told him how great must be the cost of such a work, the difficulties of which were moreover increased by the dearth of skilful draftsmen drawn away by the railroad mania, then at its height. In this doubt he had recourse to the advice of his mother. It was given in words worthy the mother of such a man: "My dear son," she said, "you have advanced far in the accomplishment of a great object, which is worthy of your ambition. You are capable of completing it. My advice is, Pursue it, even if it should oblige you to live on bread and cheese." He nobly pursued it accordingly, with unremitting toil of mind and body, as long as mental and bodily powers remained to him.*

Labours such as these would have sufficed to occupy the energy of most men. Not so Babbage. His other contributions to science and to human knowledge generally were so extensive that only some of the principal results can here be mentioned.

His memory will always be revered in this Society, in consequence of his being one of its founders, and one of its most steady supporters, until the latest period of his active life. He was very proud of being the recipient of the first medal ever awarded by the Society.

In 1828 Mr Babbage was appointed to the Lucasian Professorship of Mathematics in the University of Cambridge, a chair which had been previously filled by some of the most distinguished mathematicians of this country, including Dr. Barrow, Sir Isaac Newton, Prof. Woodhouse, and the present Astronomer Royal. This chair he held till 1839.

He took a prominent part in the founding of the British Association for the Advancement of Science, the Statistical Section of which he established. He was also the original proposer and founder of the present Statistical Society of London.

He found time to write much. His *Economy of Manufactures* is a standard work of the highest authority on the subject. His *Passages from the Life of a Philosopher*, written more

* The best account of the principles on which this engine is based is that by Menabrea, of which a translation into English, and at Babbage's suggestion extensively annotated, was made by Lady Lovelace, the daughter of the poet Byron.

recently, though containing some personal allusions which are to be regretted, but hardly to be wondered at, is one of the most interesting and amusing autobiographies ever written. His contributions to scientific and learned societies were very numerous, exceeding perhaps one hundred. They relate to almost every branch of science, physical and social; and their author being one who disdained smatterings of knowledge, and searched always for the elementary basis of every subject he undertook to examine, there is not one of these papers that does not exhibit the mastery of an exact and comprehensive mind.

The indirect effects of Babbage's principal labours cannot be estimated, and will probably never be duly appreciated but by a few. The discoveries and improvements introduced by him in the art of metallic construction are innumerable. The shaping of metals by automatic machinery, now so well understood, was an art in its infancy when Babbage was first compelled, by the necessities of his designs, to turn his attention to it. Others laboured contemporaneously at the same problems, and the names of Clement, Bryan Donkin, Maudsley and Whitworth, cannot suffer by being coupled with that of Babbage.

It is impossible in a small compass to give an adequate estimate of such an intellect. Its salient features were universality, grasp, method, patience. What do not these four qualities, inspired by intense love of truth and never-flagging enthusiasm, and sustained by enormous power of work, imply? A man to whom no branch of knowledge was distasteful or difficult,—none too large or too minute,—who by the searching faculty of analysis could, sweeping aside superficial subsidiary complexities, dive straight to the fundamental principle,—and to whom weariness and wavering were unknown weaknesses,—possessed endowments before which most obstacles must have yielded. All careers were open to such a man. In any he must have succeeded. Unhappily for himself, he chose a path which, though no other man that ever lived could perhaps have trodden it as he did, led only to loss of fortune and embitterment of mind; and though to fame, to the fame which to many will be for ever a mystery, and to the few who can prize it perhaps a regret. It is as a scientific mechanician that Babbage will hereafter, no doubt, be regarded. In this field he had no equal. The combination of the highest mathematical genius with a lofty and vivid imagination, and the power of descending to the most minute details of technical construction, has never been observed in the same degree, and well-balanced harmony of proportion, as in Babbage.

Some idea of Babbage's versatility may be gathered from the mention of some of the subjects on which he wrote—Glaciers; Uniform Postage; Parcels Post; Submarine Navigation; Magnetic and Electric Rotations; Light-houses; Light-signals; Telegraphs; Geology; Miracles; Monopolies; Locks and Lock-picking; Division of Labour; Taxation; Commerce; Wood-engraving; the Diving Bell; Games of Skill; besides numerous

contributions to Astronomy, Mathematics, and Mechanics. He wrote also the ninth *Bridgewater Treatise*. It may safely be said that he never wrote without previous study, and that nothing he has written can be read without both stimulating thought and conveying instruction.

As a man he was equally admirable — generous, just, truth-loving, disinterested beyond most men — he had the faculty of endearing himself to those who knew him. Though immersed in the most abstruse pursuits, he was yet full of human sympathies, mixing habitually during his most busy years, in the society and even in the gaieties of the Metropolis. His conversation was so easy and his nature so genial, that, wherever he went, he was a centre of attraction, particularly with the fair sex, with whom he was always a favourite. In the various notices of him that have appeared, one of his most marked qualities is strangely overlooked — namely, his love of humour; this was so strong a characteristic that, to omit it, is to omit half the man. In his most serious, and even in his most indignant moods, he would always turn aside to exhibit the ludicrous side of the question; and, to a deep-seeing intellect like his, what question has not its laughable aspect? In conversation, as in his writings, he was very fastidious in the choice of his language, which possessed the charm of power united with simplicity in a high degree. Though he entertained a high estimate of his own powers and acquirements, he was always as ready to learn as to teach; and he would seek instruction from the humblest sources. An artisan skilful in some special matter had in him a patient and deeply interested listener.

This notice, brief as it is, would hardly be complete without some allusion to Mr. Babbage's constant endeavours to suppress street music and street nuisances — for, to a considerable mass of his countrymen, he is only known as the prosecutor, or, as they may have thought him, the persecutor, of organ-grinders. When it is stated that, according to the estimate of a man so remarkable for exactness and truth, one quarter of his time was wasted by the interruptions caused by such noises; and when it is considered what that implies in the case of one who never worked languidly, but whose every available moment was employed in deep and sustained thought, the extent of this grievance will be properly appreciated. The mental distraction which external noises caused him was part of a highly sensitive organisation, — an organisation frequently associated with yearning aspirations after unattainable refinement and perfection. His case is that of many students and workers. John Leech, the famous artist, suffered severely, if not fatally, from the very same cause. Mr. Babbage put the law in action, and it utterly failed to protect him. It is not surprising that he should complain bitterly — as less eminent men than he do daily when they find that in London, beyond any place in the civilised globe, the comfort of the many is deliberately sacrificed, in this, amongst many other ways, to the vested interests of a few.

Those who only know Babbage's name in connexion with this matter, and imagine him to have been a mere peevish visionary, require to be told that no man ever more truly loved his kind, and that few men have devoted transcendent powers like his with such disinterestedness, such tenacity, and such noble self-sacrifice, to what he believed to be the profit and the elevation of humanity.

A. S.

Captain James Palladio Basevi, R.E., was a son of the celebrated architect who designed the Fitz-William Museum at Cambridge, and other important buildings, and lost his life by falling from the tower of Ely Cathedral while superintending the restoration of that edifice.

James Basevi was distinguished as a lad for more than ordinary talent, and for his mathematical abilities. After passing with great credit through Rugby, the Cheltenham College, and the Honourable East India Company's Military Seminary at Addiscombe, he obtained a commission in the Corps of Engineers as first of his term, and went out to India in the year 1853. Three years afterwards he was appointed to the Great Trigonometrical Survey of India, upon which he continued to serve up to the time of his death. He was particularly qualified for this branch of the public service, and his excellent abilities being associated with remarkable powers of perseverance, and an entire devotion of self to duty, he was soon acknowledged to be one of the most valuable officers of the Department with which his interests were inseparably bound up. He took a prominent part in each of the various branches of the operations, the triangulations, linear measurements, topography, and mathematical reductions; he completed two chains of principal triangulation of an aggregate length of nearly 300 miles, mostly over very difficult ground; he supervised the measurement of a base-line at Cape Comorin, with Colby's apparatus of compensation-bars and microscopes, and wrote a valuable paper on the probable errors of the measurement, which is printed among the Appendices to *The Account of the Operations of the Great Trigonometrical Survey of India*, Vol. i. Dehra Doon, 1870.

In 1864 Captain Basevi was selected to undertake the Pendulum Operations which were commenced at the suggestion of the President and Council of the Royal Society, for the purpose of determining the variations of the force of gravity at certain stations of the great meridional arc in India, which was measured by Colonels Lambton and Everest, and at stations on the coasts and in the interior of the British territories in Asia. The object of these operations was two-fold; first, to obtain additional data to combine with the result of similar operations in other countries for determining the figure of the Earth; and, secondly, to ascertain the magnitude of the variations which are superposed, in certain localities, on the normal increase of gravity from the equator to the poles, in order that, by comparing the force of gravity on

high-table lands, on plains little elevated above the sea-level, and on oceanic islands, some light might be thrown on the structure of the Earth's crust.

Captain Basevi entered on this work with great ardour and devotion, sparing no pains to secure results of the utmost accuracy and precision humanly attainable. His observations of pendulum and clock coincidences were continued over at least twelve days at each station, and for ten hours daily he was never absent for more than a few minutes at a time from his pendulums, the observations recurring at every hour and a half; in the evenings two hours more were devoted to star-observations for time; and the programme of work was never deviated from with the object of curtailing it, though not unfrequently additional observations were taken. Besides this, very elaborate and laborious investigations were made for the purpose of determining the values of the coefficients of temperature and pressure, and other constants, a knowledge of which was required for the reduction of the observations.

By the spring of 1869, Captain Basevi had completed the operations on the Indian Arc, and found at the northern extremity thereof a deficiency of density as the stations approached the Himalayan Mountains, and conversely an increase of density at the southern extremity as the stations approached the ocean. These results point to a law of diminution of density under the elevated, and of increase under the depressed, parts of the Earth's surface; they were subsequently corroborated by observations on the Island of Minicoy, and at various points on the coasts of the Peninsula. Comparing these *inter se*, and with the results at the inland stations, gravity was found to be greater on the island than on the corresponding coast station, and always greater on the coasts than inland on the same parallel of latitude.

Thus far, however, no very high altitudes had been visited; arrangements were therefore made to secure the crucial test of observations at altitudes exceeding 15,000 feet on the great table-lands in the interior of the Himalayan Mountains. This would complete the work in India, after which the pendulums were to be swung at Aden and in Egypt, and finally at the Greenwich and the Kew observatories, that the operations might be combined with those of Kater, Sabine, Biot, Luetke, and Sawitsch.

In the spring of the present year Captain Basevi proceeded to the interior of the Himalayan Mountains, *viâ* Kashmir and Ladak. He completed an excellent series of observations at a point in N. lat. 33° 16′, and long. 77° 54′, on a plateau at a mean elevation of 15,500 feet above the sea-level, where the force of gravity (reduced to sea-level) was found to be only as much as the normal force in the parallel of latitude of 27°, or 6° to the south of that of the station of observation. He then proceeded through the Changchenmo Valley to a plateau nearly 17,000 feet high on the borders of the Chinese territories,

and was commencing to take observations when he died suddenly after a very short illness. His death is clearly to be attributed to the privations which he had to endure in a highly rarefied atmosphere under exposure to great severities of climate, in a barren and desolate region almost wholly devoid of every necessary of life. It is the more to be regretted in that it occurred when his work was all but completed, and he was eagerly looking forward to a return to his native land with the gratification of having satisfactorily accomplished an arduous and difficult series of operations.

He died in the prime of life, at the early age of thirty-nine years. J. T. W.

Edward William Brayley* was the son of the late Edward Wedlake Brayley, well known as the author and editor of numerous topographical and antiquarian works, and for many years Librarian of the Russell Institution.

The subject of the present notice was born in London in 1801. He at the first took great interest in the studies so ardently pursued by his father, but subsequently devoted himself entirely to science, and became a student under Professor Brande, at the Royal Institution, where he made the acquaintance of Faraday and other eminent men. He also attended the lectures of Professor Millington, and attracted the attention of that distinguished philosopher, who was remarkable for the assistance he rendered his inquiring pupils. In 1824, when only twenty-three years of age, he became a Member of the Meteorological Society, and engaged in its management with Dr. Birkbeck, Mr. Luke Howard, and other distinguished cultivators of Meteorological Science. He shortly after became a lecturer on various subjects connected with science, and was closely engaged as such by the various scientific and mechanics' institutes established about that time by Dr. Birkbeck in the Metropolis and the chief towns of the kingdom. In the year 1834 the managers of the London Institution determined to engage two principal librarians, the one to take charge of the department of general literature, the other of science. Mr. R. Thomson was appointed to the former office and Mr. Brayley to the latter. He was also engaged to lecture at the Institution, and generally delivered a course of lectures on physical science during the season. He became a Fellow of various scientific and literary bodies, and joined this Society in November 1866.

On the death of Mr. Thomson, in 1865, Mr. Brayley was appointed sole principal librarian, and also Professor of Physical Geography and Meteorology to the Institution. For more than a year before his death he became subject to attacks of occasional faintness, and on the 1st of February, 1870, he expired, after twenty-four hours of severe suffering, from angina pectoris.

* This obituary notice of Mr. Brayley was received after the publication of the last Annual Report, in which it ought to have appeared.

The Rev. Alfred W. Deey, M.A., was born at Norwood on the 29th of January, 1838. He was educated at the Merchant Taylors' School, in the City of London, and in May, 1856, he matriculated at the University of Oxford, gaining a Postmastership at Merton College.

At Merton he applied himself with diligence to his College studies, and he won the esteem and respect of his contemporaries by his genial, kindly qualities, and great independence of character. In June, 1860, he took his degree, his name appearing in the Second Class Mathematical Honours. On Trinity Sunday, 1861, he was ordained by the Bishop of Bath and Wells to the Curacy of Chaffcombe, near Crewkerne, Somerset, and at the same time he accepted the post of Mathematical Master in the Crewkerne Grammar School.

The following year he entered Priests' Orders, and he remained in that position for nearly three years, during which time his very agreeable mode of imparting knowledge and his sterling good qualities were thoroughly appreciated by the able and respected Head Master, the Rev. Dr. Penney, and were further acknowledged by the boys themselves on his leaving them, by their presenting him with a handsome telescope.

In April, 1863, he proceeded M.A., and shortly afterwards was appointed Senior Curate of Alton, Hants. Here he laboured for several years, and devoted himself, with all the ardour of his nature, to the faithful discharge of the various duties that devolved upon him in such a large parish. In July, 1869, he was presented to the vacant living of Hartley-Mauditt, near Alton, and in 1870 he was also appointed Vicar of the adjoining small parish of West Wooldham.

From quite early years he had manifested a strong bent in favour of astronomical studies, and he never lost an opportunity of improving himself in them. In January 1866 he was elected one of the Fellows of this Society, and his name may often be seen in the *Astronomical Register* as a correspondent, particularly in a lengthened reply, in the April number of 1870, to a letter from Mr. Elvins on the motion and physical constitution of the Moon. With the assistance of a powerful telescope he made a frequent examination of the spots on the Sun, and made sketches of their appearance from time to time, until interrupted by illness. Mr. Deey died at the early age of thirty-three, respected by his parishioners and numerous friends, who deplore his premature loss.

Professor De Morgan was born at Madura, in Southern India, in June, 1806. Several members of his father's family had distinguished themselves in the Indian army. His great-grandfather and grandfather had fought under Warren Hastings, and his father, Colonel John De Morgan, was a man of considerable energy. But it was from the maternal side that he must have inherited his mathematical powers. His mother was a grand-

daughter of James Dodson, F.R.S., author of the *Anti-logarithmic Canon*, a pupil and friend of De Moivre's, and master of the Mathematical School of Christ's Hospital; he was also the chief founder of the Equitable Life Assurance Company, for which he calculated the first tables.*

In August, 1806, Colonel De Morgan and his wife returned to England, bringing with them a daughter, and their infant son, Augustus, then three months old. He had been born with but one eye, but was a strong child. On arriving in England, they first settled at Worcester, and then lived rather a migratory life, moving from place to place in the west of England. When the Professor was between four and five, he remembered his father giving him his first lessons in arithmetic. After a few years Colonel De Morgan returned to India, again leaving his wife and children in this country. And while on his way to England in 1816, he was taken ill and died at sea off St. Helena, leaving his widow with four children. The little Augustus was then a boy of ten, and passed from one private school to another, being crammed with general knowledge, Latin, Greek, and even Hebrew, before he was fourteen. In after life he had a strong aversion to the overstrained education of young children; he hated cramming, and the competitive examinations of the present day, believing them to be an almost unmixed evil, against which, however, it was in vain to remonstrate; the errors which he deplored would only become apparent by their fatal results in the next generation. At the age of sixteen and a half he passed on to Cambridge, where he entered at Trinity College. His rooms were in the south-east corner of the Great Court, then called "Mutton Hole Corner," which he used to affirm was a corruption of Merton Hall Corner. Here he spent his undergraduateship, and greatly developed his love for mathematics, which had already begun to show itself before he left school. He, however, indulged his musical tastes, learning to play the flute, of which he is said to have been one of the best amateur players in England, and also spending much of his time in general reading, which greatly interfered with his study for honours. One of his college lecturers was Mr. Airy, who had been senior wrangler of the year in which the young De Morgan entered.

He had not completed his twenty-first year when he gained the fourth place in the mathematical tripos of 1827, the order of the list being Gordon, Turner, Cleasby, De Morgan. The place of the youthful wrangler, though it failed to declare his real

* He wrote many books besides the *Anti-logarithmic Canon*, which was a work unique of its kind, containing the number to eleven figures corresponding to every logarithm from ·00001 to 1·00000. The author is said to have corrected the faults in most copies with his own hand. He wrote a quarto book on the method of book-keeping, of which Professor De Morgan says in his *Arithmetical Books from the invention of printing to the present time*, 1847, at page 71, "As far as I can find, this is the first book in which double entry is applied to retail trade."

power or the exceptional aptitude of his mind for mathematical study, would, however, have been sufficient to have secured for him a fellowship, and he, no doubt, would have found a congenial field of labour within the walls of his university, if his conscientious scruples had not prevented his signing the tests which at that time were required from those who took up their degree of M.A. as well as from all Fellows of Colleges.

In his later years he termed himself with characteristic pleasantry, "A Christian Unattached," and the considerations which caused him to describe thus negatively his religious position were so far operative on his conscience in early manhood, that he forbore to secure a high wrangler's ordinary share of University preferment by formal, and what would have been, to him, insincere subscription.

In 1863 he wrote, "What is belief? A *state* of the mind. What is it often taken to be? An *act* of the mind. The imperative future tense—I will believe— thou shalt believe, &c.—which has no existence except in the grammar-book, represents a futile attempt which people make upon themselves and upon others." This sentiment, expressed so forcibly in his later life, was the moving power which, when he was on the threshold of manhood, caused him to withdraw from the University in which he would, doubtless, have become a powerful leader of mathematical thought, had his religious feelings been less acute or his principles more elastic.

On coming to London, he entered at Lincoln's Inn, and would have been compelled to forsake mathematics for the study of the law, but that, in 1828, the University of London, now University College, was founded, and he was appointed to the mathematical chair. In May of the same year he became a Fellow of this Society, and in the following November gave his first introductory lecture at University College. In his own words, he then "began to teach himself to better purpose than he had been taught, as does every man who is not a fool, when he begins to teach others, let his former teachers have been what they may."

In 1837, ten years after his appointment at University College, he married Sophia Elizabeth, the daughter of Mr. William Frend,* formerly a Fellow of Jesus College, Cambridge, author of several mathematical books, and Actuary of the Rock Life Assurance Office. The professional experiences of his father-in-law opened to De Morgan a fresh sphere of labour, in which he turned his mathematical acquirements to account in the service of many of the London Insurance Companies. In this new field of labour he might, doubtless, have made a much larger income than he could ever hope to derive from his professorship at University College, but he was devotedly attached to the principles of the new institution, and made it his first duty to advance its interests.

* Mr. Frend was a fellow of this Society; his obituary notice, written by Professor De Morgan, will be found in vol. v. of the *Monthly Notices*, p. 144.

He was so punctual and so regular in the performance of his college duties that his passage to and from his classes served as a time-piece to observant students. Soon after eight o'clock every morning he might have been seen passing along the railed enclosure of University College, so absorbed in thought that his nearest friends might pass him without being recognised.

He remained a firm supporter of the institution and its principle of no religious tests till the year 1866, when the Council, in making an appointment to the chair of Logic and Mental Philosophy, refused, as the Professor believed, one of the candidates on account of his religious opinions. Professor De Morgan, acting under the conviction that the Institution to which he had devoted the best years of his life, was forsaking the leading principle on which it had been founded — a principle which from early manhood had influenced him, and was now dearer to him than ever—felt it his duty to resign his professorship.

And thus, though deeply disappointed and grieved at the step he felt forced to take, Professor De Morgan, who had for nearly forty years been the chief honour and ornament of University College, left it, and, we are informed, never afterwards entered its gates.

To estimate the energy of the Professor, we must look at him not only as a teacher of mathematics, but as a mathematician, an actuary, a logician, an historian, a biographer, and a bibliophile.

First, then, as a teacher of mathematics; perhaps no man has been more successful in training distinguished mathematicians, amongst whom we may mention the names of Professor Clifton, Judge Hargreave, Mr. Routh, and Mr. Todhunter. Professor Sylvester also attended his lectures, though the relationship of professor and pupil did not in this case last very long. He had a method of interesting his hearers in the subjects on which he lectured, and of making them love mathematics for its own sake, to which few other men have ever attained. He devoted more time and labour to the logical processes by which the various rules are demonstrated than to the more technical parts of his subject, though of these too, in their proper place, Professor De Morgan was never unmindful, spending the greatest care on teaching the art of rapid and accurate computation.

His exposition of the elementary principles of the Differential Calculus, and of the logical processes of his Double Algebra, was most masterly and exhaustive, and was often enlivened by such humorous illustration that it never failed to impress itself upon the minds of his hearers. The subject-matter of every lecture which he delivered was entered by him in a note-book, and was sent into the library of the college for the benefit of his pupils while writing out and expanding their own notes.

As a mathematician his work was so various that it would be difficult for any one man to review it; but we may allude, in passing, to his double algebra, which was certainly the forerunner

of Quaternions, and contained the complete geometrical interpretation of the $\sqrt{-1}$. Sir William Rowan Hamilton, in the Preface to his *Lectures on Quaternions*, at p. 41, says: "But I wish to mention that, among the circumstances which assisted to prevent me from losing sight of the general subjects, and from wholly abandoning the attempt to turn to some useful account those early speculations of mine on triplets and on sets, was probably the publication of Prof. De Morgan's first paper on the Foundation of Algebra, of which he sent me a copy in 1841." And at p. 64 of the same Preface he says, in speaking of this theory of Sets of which he considered Quaternions (in their *symbolical* aspect) to be merely a *particular* case, "Before the publication of those *sets*, the closely connected conception of an '*algebra of the nth character*' had occurred to Prof. De Morgan in 1844, avowedly as a suggestion from the Quaternions.' A great portion of his original investigations will be found in the form of communications to the *Transactions of the Cambridge Philosophical Society*."*

As a writer of mathematical text-books he took the highest rank, his books being more suitable, however, for teachers than for pupils. They were characterised by extreme clearness, exhaustiveness, and suggestiveness. Perhaps those best known are his *Elements of Arithmetic*, published 1830; his *Elements of Algebra*, published 1835; and his *Differential and Integral Calculus, with Elementary Illustrations*, which is a perfect mine of original thought, and in which some of the most important extensions which the subject has since received are distinctly foreshadowed. It was published by the Society for the Diffusion of Useful Knowledge.

His first mathematical text-book was a *Translation of the Elements of Algebra by Bourdon*, published when he was only twenty-two years of age. He wrote text-books upon trigonometry, double algebra, the theory of probabilities, connexion of number and magnitude, projection, and the use of the globes; besides which he edited more than one table of logarithms, and wrote prefaces and notes to the books of other mathematical authors. The list of his works and their various editions occupies nine pages of the British Museum Catalogue.

As an actuary he occupied the first place, though he was not directly associated with any particular office; but his opinion was sought for by professional actuaries on all sides, on the more difficult questions connected with the theory of probabilities, as applied to life-contingencies. In 1830 he wrote for the *Cabinet Cyclopædia* his "Essay on Probabilities,"—a book which still retains a high place among the literature of insurance offices.

* The Royal Society's Catalogue of Scientific Papers gives a list of forty-two communications by Prof. De Morgan, mostly in the following publications:—*The Transactions of the Cambridge Philosophical Society*, *The Cambridge Mathematical Journal*, *The Cambridge and Dublin Mathematical Journal*, *The Philosophical Transactions*, and the *Memoirs* and *Monthly Notices of the Royal Astronomical Society*.

As a logician he was well known, and his *Formal Logic*, together with the treatise of Dr. Boole, may be said to have created a new era in logical science. His controversy with Sir William Hamilton will long be remembered.

As an historian and biographer the *English Encyclopædia* says of him, that "he had a great affection for, and an extensive and minute erudition in, all kinds of literary history, biography, and antiquities." He was one of the most extensive contributors to the *Penny Cyclopædia*, many of the articles of scientific biography having been written by him, as well as most of the mathematical and astronomical articles. His contributions to the work are said to amount to one-sixth of the whole Cyclopædia. The lives of Newton and Halley, in Knight's *British Worthies*, were also from his pen. Besides these he published an index of the correspondence of the scientific men of the seventeenth century; and a book entitled *General Information on Subjects of Chronology, Geography, Statistics, &c., References for the History of the Mathematical Sciences*, 1842.

As a bibliophile, his *Arithmetical Books from the Invention of Printing to the present time*, 1847, and his *Budget of Paradoxes*, will long remain celebrated. A reprint of the latter, greatly enlarged from manuscript notes left by the Professor, is now being taken through the press by his widow. He was the possessor of a very choice collection of mathematical works, which have, since his death, been purchased by Lord Overstone, and presented to the University of London, where they now form a De Morgan Library ; most of the volumes contain bibliographical notes and sometimes quaint and humorous scraps from newspapers or other books pasted into their covers.

He was a true bibliophile, and revelled in all the mysteries of watermarks, title-pages, colophons, catchwords, and the like. He wrote in the preface-dedicatory of his list of arithmetical books, "The most worthless book of a bygone day, is a record worthy of preservation. Like a telescopic star, its obscurity may render it unavailable for most purposes ; but it serves, in hands which know how to use it, to determine the places of more important bodies."

In addition to this, the Professor contributed largely to the *Philosophical Magazine*, the *North British Review*, the *Athenæum*, the *Companion to the Almanac*, and *Notes and Queries*. The *Athenæum** says of him, that if all the articles which he contributed to literary and scientific journals were collected together, there would be found such a mass of literary achievement as seldom comes from the pen of a man whose sole business is to write for journals. He also compiled a *Book of Almanacs*, with an index of reference, by which the almanac may be found for every year up to A.D. 2000, with means of finding the day of the new moon from B.C. 2000 to A.D. 2000, published 1851.

* March 25, 1871, p. 370.

The Professor also devoted much of his time to the business of this Society. For a period of more than thirty years he was officially connected with it, sometimes serving upon the Council, sometimes as Vice-President, and for many years as Secretary, in conjunction with Mr. Bishop and Admiral Manners, and during this period many of the volumes of the *Monthly Notices* were produced under his editorship.

He was the first President, and took great interest in the formation of the London Mathematical Society, of which his son, the late George Campbell De Morgan, was one of the first honorary secretaries. Soon after the untimely death of this son, who was a mathematician of considerable promise, he wrote to one of the early officers of the Mathematical Society, "My son's loss has thrown much grief over my house, but no gloom. He is spoken of as if he were removed to be followed in time, and to be kept in memory all the more, because he is no longer to remind us of himself by his direct presence. . . . I make out distinctly, from written evidence among his papers, that you and he were the projectors of the Mathematical Society . . . . and I wish to have the evidence of this very distinctly preserved. There is quite enough in my hands to establish the fact, but I should be glad of every detail that you can remember."

A very inadequate notion of Professor De Morgan will be formed by those who look only at his works. From them, indeed, it will be seen that he was a reader who relished every kind of intellectual food, and a thinker whose subtlety was only surpassed by his originality. They abound also with proof that he overflowed with humour; but his familiar associates alone can render justice to the versatility of his powers and the sweetness of his disposition.

Knowing many subjects thoroughly, there was scarcely one about which he did not know much.* He passed, for diversion's sake, from one arduous study to another, but though he found a pastime in intellectual efforts that would exhaust ordinary students, he did not disdain literature that pedants are apt to contemn as frivolous. He was an habitual and eager reader of novels, especially humorous novels, but there were times when, in the absence of a good novel, he could enjoy a bad one. The paradoxers, whom he infuriated by his banter, were strangely at fault when they accused him of malignity. He was the kindliest, as well as the most learned, of men—benignant to every one who approached him, never forgetting the claims which weakness has on strength. Soon after the death of his son the Professor was attacked with a disease of the kidneys, which during more than two years of distressing illness reduced him to a shadow of his former self; and on Saturday, the 18th of March, 1871, at one o'clock in the afternoon, his spirit was released from the body, which had long been only a burden to it.

* One of his favourite maxims was, "A man should know everything of something, and something of everything."

Lieut.-General Sir William Thomas Denison, K.C.B., R.E., was born in 1804. He was the son of John Denison, Esq., M.P., of Ossington, and brother of the Rt. Hon. John Evelyn Denison, M.P., Speaker of the House of Commons, and of the late Dr. Denison, Lord Bishop of Salisbury. After completing his preliminary studies, he entered the Corps of Royal Engineers, in which he was distinguished as one of the most successful of the scientific officers employed under the direction of Colonel Colby, Superintendent of the Trigonometrical Survey of Great Britain. While serving with his corps, he was frequently employed by Government on special engineering duties in England and the colonies. On Lieut. Denison's return from Canada, where he was engaged on the construction of the Rideau Canal, he was placed in charge of the course of Topographical instruction for Engineer Officers and Sappers at Chatham, in connexion with which he established an astronomical observatory. He subsequently had control of the works at Woolwich and Portsmouth Dockyards, employing his leisure time in editing the first series of Corps Papers on subjects connected with civil engineering. He became a Fellow of the Royal Astronomical Society in 1834, and of the Royal Society in 1838.

The administrative ability of Captain Denison having been brought under the notice of the Secretary of State for the Colonies, he was appointed, in 1846, to the office of Lieut.-Governor of Tasmania. About the same time he received the honour of knighthood. In 1854, he was removed to Sydney, as Governor-General of Australia, and finally he was translated in 1860 to the Governorship of the Madras Presidency. This latter tour of duty included a brief episode as acting Governor-General of India, during the few months' interval after the death of the Earl of Elgin in 1863, and the arrival of his successor Sir John Laird Mair (now Lord) Lawrence. Sir William Denison's brief administration of this high and responsible office gave complete satisfaction to the Home Government. He resigned his appointment as Governor of Madras in 1866, and returned to England in May of that year, thus closing a successful career as a Colonial Governor for the long period of twenty years.

While at Sydney and Madras Sir William Denison took a great interest in the promotion of astronomical observations in connexion with the established observatories at these places, and he was ever ready to support anything which he considered advantageous towards the progress of Astronomy. During his long absence from England he never failed to carry on a frequent correspondence on astronomical and other scientific questions with some of the principal philosophical minds of this country, by some of whom he was much esteemed.

Sir William Denison married, in 1838, Caroline Lucy, daughter of Admiral Sir Phipps Hornby. He was made a Knight Companion of the Bath in 1856, a Major-General in

March 1868, and a Lieut.-General in the latter part of 1870. After his return to England, he employed his leisure time in the preparation of his most characteristic work, *Twenty Years of Vice-Regal Life;* and after a few years of arduous application to the duties of a River Commissioner, as well as much attention bestowed on colonisation, he was called hence, after a very brief illness, on the 19th of January, 1871, in his 67th year, in all the honours of deep and unfeigned attachment amongst his personal friends; and amongst those who only knew him in public life, with all the respect due to his unblemished career as a "soldier, an officer, and a gentleman,"—such at least is the testimony of a few brother officers who have been privileged with his friendship during half a century.

Edwin Richard Windham Wyndham Quin, Earl of Dunraven and Mount Earl, was born at Adare Manor, in the county of Limerick, on the 19th of May, 1812. He was Lord Lieutenant and Custos Rotulorum of the County of Limerick, Knight of the order of St. Patrick, and a Commissioner of National Education in Ireland. From the year 1837 to 1851 he represented Glamorganshire in Parliament. He was a man of singular accomplishments, and an earnest student of science.

Lord Dunraven was educated at Eton, and Trinity College, Dublin. He was at that time devoted to the science of astronomy, and made it an essential condition of his entering college that he should be prepared for it under the tuition of Sir William Hamilton, to whom he was introduced by his friend Dr. T. Romney Robinson, of Armagh. He resided for about two years at the Dublin Observatory, where he devoted himself earnestly to observing-work, and on one night alone he observed as many as 150 transits of stars. Such labour, however, proved injurious to his sight, the failure of which prevented him carrying out his intention of erecting at Adare a first-class observatory. His interest in the science, however, remained unabated. He became, in the year 1831, a Fellow of the Royal Astronomical Society. His visits to the late Lord Rosse and the late Mr. Cooper, of Markree, were sources of unmixed delight to him, as affording him the opportunity of resuming his favourite study; and towards the close of his life he watched with intense interest the construction of the great Melbourne telescope in Dublin. He was also an excellent practical geologist and botanist, and gifted with a singular appreciation of and intense enjoyment in Nature.

In the year 1840 Lord Dunraven formed the acquaintance of the late Dr. Petrie, and from this and the influence of the warm friendship which sprang up between them may be dated the commencement of his devotion to the science of archæology. He had watched the stoppage of the Ordnance Survey of Ireland with the same deep regret that was felt by all the enlightened men of the country, and in 1843 it was through his energy that a large and

remarkable meeting was held in London, at his house in Eaton Square, the result of which was that the then minister, Sir Robert Peel, consented to appoint a commission to take evidence and make a report on the entire question. This commission—consisting of Lord Dunraven (then Viscount Adare), Mr. Young (one of the Lords of the Treasury), and the Clerk of the Ordnance (Captain Boldero)—held their first meeting on the 14th of July, and presented their report in the following November; and among the multitudinous reports of commissions in reference to Ireland, it may be safely said that, whether the subject-matter or the character of the witnesses be considered, there are few others possessing so deep an interest. It does not deal with any political question, but with matters much more closely allied to the real interests of the country, and which come home in an especial manner to the minds of all who have her social welfare and material progress at heart.

In the year 1830 Lord Dunraven became a member of the Royal Irish Academy, of which he was afterwards a Vice-president and Member of Council. In 1834 he was elected a Fellow of the Royal Society, and in 1837 of the Royal Geographical Society. He was also a Fellow of the Geological Society, and a Member of the British Association for the Advancement of Science. He laboured with his usual energy in the formation of the Irish Archæological Society, founded in the year 1840, and the Celtic Society, founded in 1845; and to him were dedicated some very important works connected with the history of Ireland, such as the *Annals of the Four Masters*, translated and edited by O'Donovan; the *History of the Ancient Ecclesiastical Architecture of Ireland*, by Dr. Petrie; and the third volume of *Les Moines d'Occident*, by the Comte de Montalembert, which contains the life of St. Columba, and the history of the conversion of Ireland by the monks.

Lord Dunraven presided over the meeting of the Cambrian Archæological Association held at Bridgend, Glamorganshire, in 1869. The duties of the president at these annual meetings are always of an arduous nature, but with a courteous manner and a kindly disposition, combined with the accuracy of a local antiquary and the breadth of view and tolerance of a sound comparative archæologist, Lord Dunraven discharged these duties in the most admirable manner, both in the field and at his Welsh residence, Dunraven Castle, Glamorgan; and his address at the meeting was a well-studied epitome of the archæology of the district which was about to be explored.

In 1866, Lord Dunraven and some friends formed themselves into a committee for the sale of the museum collected by Dr. Petrie, who died in that year; and for the arrangement and publication of his posthumous works. At this time the idea suggested itself to him of completing the work left unfinished by Dr. Petrie, of the *History of the Ancient Ecclesiastical Architecture of Ire-*

land; and for four years afterwards he laboured hard and travelled through the country, photographing all the principal ruins, making measurements and ground-plans and descriptive notes for his book. While thus engaged his health broke down, and he never lived to accomplish the work commenced and carried on with so much fervour. In his will he has bequeathed a large sum towards the publication of this series of photographs, which will illustrate the ancient architecture of the country, commencing with the great forts of the pre-historic period, and forming a regular progression to the time of the Anglo-Norman invasion.

Lord Dunraven married twice. His first wife was Augusta, third daughter of Thomas Goold, Esq., Master in Chancery — a lady of singular talent and acquirements, a true musician and artist, while wise and full of charity in her domestic and social life. She died in 1867, and he afterwards married Anne, daughter of the late Henry Lambert, Esq., of Carnagh, who was M.P. for the county of Wexford in the year 1833.

For some time previous to his death Lord Dunraven's health had been breaking. At Malvern, on the 6th of October, 1871, he sank to rest, surrounded by his family, who watched him to the end.

Commander Robert William Hale Hardy was one of the many naval officers who have from time to time shown an interest in astronomical pursuits. He entered the navy in 1806, as a second-class boy on board the *Ganges*, 74, Captain Peter Halkett. While serving, in 1810–11, in the *Caroline*, 36, Captain Christopher Cole, he assisted in the celebrated capture of Banda Neira, and of the Island of Java. He was also present at the siege of New Orleans in 1814. After his promotion to the rank of Lieutenant, on the 20th of February, 1815, he never served afloat. Commander Hardy joined the Royal Astronomical Society in 1849, and was a contributor on several occasions to the *Monthly Notices*. He was the possessor of a good telescope and some other astronomical instruments. He died at Bath in 1871, at an advanced age.

The name of Herschel, mentioned in this the sadder portion of our anniversary proceedings, calls forth one of the best and deepest of our emotions, veneration for the memory of an illustrious man and faithful friend departed to his rest; but not departed before the imperishable labours of a long life had been nobly accomplished. From ourselves this tribute of respect is especially due, inasmuch as from the earliest rise of our Society until now that it has passed its fiftieth year, John Herschel promoted and adorned its progress in all kindly offices and with a constant solicitude. With the single exception of his early friend Babbage, who survived him but a few months, he was the last of that list of admirable men who launched the Royal Astronomical Society on its career of eminent

success and scientific usefulness. Happily their mantle has descended on successors still left to us, able and worthy to carry on the work which those men commenced so well. We have entered on the harvest of our fathers' labours, rejoicing in the not less successful efforts of their sons.

John Herschel was born at Slough, on March 7, 1792, in that house which his father's discoveries have rendered historical. A few traits of his boyhood, mentioned by himself in his maturer life, have been treasured up by those who were dear to him, and the record of some of them may satisfy a curiosity as pardonable as inevitable, which craves to learn through what early steps great men or great nations become illustrious. His home was singular,—and singularly calculated to nurture into greatness any child born as John Herschel was, with natural gifts capable of wide development. At the head of the house there was the aged, observant, reticent philosopher; and rarely far away, was his devoted sister, Caroline Herschel, whose labours and whose fame are still cognisable as a beneficent satellite to the brighter light of her illustrious brother. It was in the companionship of these remarkable persons, and under the shadow of his father's wonderful telescope, that John Herschel passed his boyish years. He saw them, in silent but ceaseless industry, busied about things which had no apparent concern with the world outside the walls of that well-known house, but which, at a later period of his life, he, with an unrivalled eloquence, taught his countrymen to appreciate as foremost among those living influences which best satisfy and elevate the noblest instincts of our nature. What sort of intercourse passed between the father and the boy, may be gathered from an incident or two which he narrated as having impressed themselves permanently on the memory of his youth. He once asked his father what he thought was the oldest of all things. The father replied, after the Socratic method, by putting another question, "And what do you yourself suppose is the oldest of all things?" The boy was not successful in his answers, whereon the old astronomer took up a small stone from the garden-walk: "There, my child, there is the oldest of all the things that I certainly know." On another occasion his father is said to have asked the boy, "What sort of things, do you think, are most alike?" The delicate, blue-eyed boy, after a short pause, replied, "The leaves of the same tree are most alike to each other." "Gather, then, a handful of leaves from that tree," rejoined the Philosopher, "and choose two that are alike." The boy failed; but he hid the lesson in his heart, and his thoughts were revealed after many days. These incidents may be trifles; nor should we record them here, had not John Herschel himself, though singularly reticent about his personal emotions, recorded them as having made a strong impression on his mind. Beyond all doubt, we can trace therein, first, that grasp and grouping of many things in one, implied in the stone as the oldest of things; and, secondly,

that fine and subtle discrimination of each thing out of many like things, as forming the main features which characterised the habit of our venerated friend's philosophy.

In due time he was sent to Eton. It was close to his home; too close, indeed, for the jealous inspection of a mother's eye, for it was not long before she saw him maltreated by a stronger boy, and he was removed from the great school. Perhaps happily so, for the atmosphere of the public schools of that day was not suited for the nurture of a philosophical astronomer. Thus he was educated at home; and how successful that education was is written in the volumes and the manners of his life; for John Herschel became every way an accomplished man; he was a good and a fond scholar, an excellent modern linguist, a musician, and accomplished in the literature of the day. He always spoke affectionately of his tutor Mr. Rogers, but that gentleman does not appear to have been more successful in his attempts to impart a knowledge of geometry to his illustrious pupil than are the majority of the tutors of the present day; for John Herschel has been known to state that he learned Euclid accurately and diligently, but that "he knew no more of its real bearing and intention than he knew of the man in the moon." This is a pity, but we have much reason to fear that this is a pitiably common result. Perhaps no one would be more amazed than the great Geometer of Alexandria himself, if he were to return to life and find that his books, written for mature philosophers, were put without note, comment, or preparation, into the hands of the boys of the nineteenth century, to flounder therein just as they may chance.

Be this as it may, Herschel was sent to Cambridge at the unusually early age of seventeen.

His University career would no doubt have been eminently successful to whatever college he might have been sent, but he must have found a great facility for the development of his natural bias in having been entered by his father at St. John's. That College was then, and has ever since been, conspicuous for the careful and judicious training and the generous encouragement of its younger members in every branch of academical learning, and we venture to say that in none was, or is, the *Principia* of Newton studied with greater intelligence or devotion. In Herschel's day, and for many subsequent years, this immortal work was presented to the students in the form of manuscripts, in which the prescribed sections of the book were provided in an English dress. Herschel, however, made it his duty to read nearly the whole book in the original Latin. This is one instance out of many others, of that thoroughness of work which he displayed through life; it was the bent and genius of his mind; it was the happy tradition of his home. With such natural gifts developed by so able a training, it is no wonder that Herschel graduated as the Senior Wrangler of his year. Peacock, afterwards Dean of Ely, a man of rare ability, was the

second on the list, followed by several others who became conspicuous in their day.

It is well known that great changes were imminent at Cambridge in the form of the study of mathematical learning at the time when Herschel was an undergraduate. From a variety of causes, not very easily understood, mathematical analysis had not made that advancement in England which had been so remarkable on the Continent ever since the death of Newton. The Cambridge professors and teachers acted as if they had a vested interest in the powerful geometry of the past; many of them were possessed of vast mental capacity, but they continued to encumber themselves with an old fluxional notation, and ponderous methods, which had long been discarded by the philosophers abroad. Waring at Cambridge and Lagrange at Turin were both born in the same year, 1736; both of them wrote—and wrote ably—on the same subject, the *Theory of Numerical Equations*, yet the difference between the notations and even the methods of the two analysts, is something incredible to a person who has never taken the trouble of making the comparison. But it was not Cambridge alone which was in fault; a similar remark is applicable to the writings of Thomas Simpson in London and Euler at St. Petersburg. Yet the two Englishmen were probably endowed with natural genius comparable with those of their foreign compeers.

It was Woodhouse at Cambridge who first applied himself seriously and systematically to remove this stigma and this obstacle to all true scientific progress. He paved the way to ultimate success, not so much by his deeper and more controversial treatises, as by an elementary work on Trigonometry, which for the first time opened the door of the Continental forms of analysis, to the English student. This able and important, though elementary treatise, was published in the year when Herschel joined the University, and the influence which it had upon his mind is evidenced by the fact that the first contributions which he made, and that too during the years of his undergraduateship, to a scientific periodical of the day, were based on what he had read in Woodhouse's book. It was natural also that Herschel, even before his degree, should warmly espouse and effectually assist the cause in which his senior was so actively engaged.

One of Herschel's first works after his degree was an effort in the same direction, namely, to render the magnificent methods and results of analysis, which had so long been familiar to the minds of foreigners, accessible to the English student. With this view, and in conjunction with two of his university friends, he translated the best elementary treatise of that day on the *Differential Calculus*, adding, thereto, a valuable appendix on the cognate subject of Finite Differences from his own hands. Not long after this, the same zealous mathematicians added a collection of examples and methods of the higher forms of analysis, which

utterly revolutionised the form of mathematical science, not at Cambridge alone, but throughout the country. In the parts added by Herschel and Babbage, that containing the finite differences by the former, and that containing a theory of functional equations by the latter, there was much that was striking and original. It was mainly by the writings of these eminent men, that the foundation was laid for that brilliant school of English analysts who are now, at least, the equals of their compeers on the Continent. It were invidious to name the living, but we may cherish a pardonable pride in being permitted to number two of this great school among the former Presidents of our Society, and to-day we hope to add a third to the list.

We have thus traced the career of Herschel up to, and just beyond, the time when he took his Bachelor's degree at Cambridge; and we shall merely add, that the authorities of the venerable College to whose fostering care he owed so much, cannot fail to read with peculiar pleasure the name of Herschel inscribed among the former fellows of their ancient house. Omitting here all notice of his earlier contributions to Nicholson's *Philosophical Journal*, and to the *Cambridge Analytical Society* of his own day, we come to his first communication to the Royal Society. It is dated from Slough, Oct. 6, 1812, and must therefore have been completed in the last long vacation of his undergraduateship, three months before his final examination for his degree. It bears the significant notice "*Communicated by William Herschel.*" It related to "Some Remarkable Applications of Cotes' Theorem," and was probably suggested by an elegant theorem of Vieta's, printed in *Woodhouse's Trigonometry*, but it proceeds far beyond any conception which seemed to have presented itself to Vieta's mind. In 1814 we find a second paper of his in the same Transactions, but it is now communicated in his own right as a Fellow of the Society. It is a paper of remarkable elegance and of subtle conception, entitled "Considerations of Various Points of Analysis;" he therein devotes himself to the development of generating functions, a branch of analytical mathematics which had successfully engaged the attention of Laplace. It is in this paper that he first discloses the true bent and fashion of his maturer mind; the natural fruit of that early direction of his thoughts indicated by the incidents of the stone and the leaves already narrated. He intimates that mathematical science having now made vast strides in the various details of its several distinctive branches, further progress was not now to be looked for in the direction of specific and isolated methods, but that the time was come when philosophers should look for some methods of expressing the results of their labours *as a whole*. He says, "Henceforth the attention of the scientific observer must be directed to those elevated stations from which distinct and extended views of the arrangement of this science *as a whole* can be obtained." It is this grouping of things together as a whole, which constituted an eminent characteristic of

Herschel's philosophy. With him it is not the age of this thing or of that thing, but the oldest of all things aged.

This paper is followed up by other communications on mathematical analysis, all written in the same spirit, and pursuing the same vein of inquiry. Herschel, however, quitted Cambridge soon after his degree, and placed himself in the hands of an eminent Chancery barrister in London with the view of qualifying himself for practice at the Bar. The arrangement in itself was natural enough, for the higher wranglers in the Cambridge tripos of Herschel's time, who selected the Law for their profession, almost universally rose to eminent stations among the chiefs in Chancery, or on the judicial bench. The names of Copley, Pollock, Bickersteth, Maule, Page Wood, and a host of others, bear witness to the happy results of the Cambridge training. And if a less amount of success has been attained by them in more recent times, whatever the other reasons may be, we venture to say that one of the efficient causes may be found in the modern comparative abandonment of the geometrical method. The educational effects of the continued study of abstract analysis do not easily comport with the composite circumstances of ordinary life, wherein lies the chief field for the application of the Law. Be this as it may, a mind constituted like Herschel's, and trained, as his had been trained, in the love of generalisation, was not likely to submit voluntarily to the mastery of isolated facts and precedents bound together apparently by no ties of a general law. Whether this was the cause or not, certain it is that he emancipated himself from studies which were essential to success at the English Bar.

Nevertheless, his removal from Cambridge to London proved to be the turning-point of his scientific career. For it was in London that he made his acquaintance with Wollaston and with South. Wollaston completely fascinated him by the breadth and accuracy of his scientific pursuits, and fostered, if not awakened, in him that dormant taste for Chemistry and general Physics which wanted but the magic touch of such a mind, to kindle into the intellectual passion of a life. We think we may aver this with safety, for we have heard him more than once say that he became an Astronomer, not so much from any conscious and specific aptitude for the work, as through a loyal desire to re-examine and complete his father's work: had he followed simply the natural bias of his mind, his pursuits would have been the study of Chemistry and of the Theory of Light.

Hence it is that in 1819 we find him communicating to Nicholson's *Philosophical Journal* a very remarkable article on Hyposulphurous Acid and its compounds. He therein details the important and indeed the cardinal discovery of that property of hyposulphite of soda, which, had it been known to Wedgwood or Davy, would have anticipated the photographic invention of Neipce and Daguerre by a quarter of a century. "Muriate of silver freshly precipitated," he says, "dissolves in this salt (hyposulphite

of soda) when in somewhat concentrated solution, in large quantity, and almost as readily as sugar in water." What would Davy have given for the knowledge of this discovery, when he shut up his Sun-pictures in the darkness of a portfolio, only to elude him like ghosts in daylight? This was immediately followed by his first paper on physical optics, a subject which, as we have said, had a peculiar attraction for him; and here again we find an instance of his love of generalisation, for he applies the known action of grooved or striated surfaces on light to explain the iridescence of mother-of-pearl. Then, again, in the same year, there is a communication made to the Royal Society, on another optical question, much more recondite in its nature: he investigates the coloured lemniscates produced by certain biaxal crystals, when submitted to the passage of polarised light, and he proposes certain simple and elegant devices for the observation of these and similar gorgeous phenomena sometimes adopted even at the present day.

Lastly, there came a very important paper addressed to the Royal Society on the subject of aplanatic combinations for the object-glass of a telescope. There is great power and mathematical elegance in the management of the symbols, and the way in which he proposes to employ one of the disposable constants, so as to make the combination equally aplanatic within a considerable range of distance, is ingenious in the extreme. Practical opticians, however, have not generally availed themselves of this form, because other forms are of less difficult execution. Moreover, now that the manufacture of glass admits of apertures which Herschel never dreamed of, it is found that, however useful mathematical formulæ may be for a first approximation to the proper form of the components of a large object-glass, nevertheless when this approximation has been executed, the achromatism requires a subsequent manipulation, often expressed by the significant term "finishing," which must be effected by the skill and experience of the artist, rather than from abstract calculation. Still Herschel's investigation is effective for moderate apertures, and for a camera applied to landscapes might be very beautiful.

It was about this time also that the influence of Mr. South produced a decided effect upon his pursuits. That gentleman was possessed of some of the best achromatic telescopes of the day, small as they were compared with the gigantic machines of more modern times. He had a passion for practical Astronomy, and had by himself done some very creditable work on double stars. It was a happy circumstance for him and for science that he could be associated with such a mind as Herschel's. Their conjoint labours commenced about the same time as the first formation of our own Society, South himself having a large share in the scheme which has been so successfully developed during the last fifty years. The venerable Sir William Herschel was its first President, and his illustrious son its first Foreign Secretary. The early lessons in the historic house had been well learnt, and

the teacher was well rewarded, by this happy and significant association.

Herschel's first communications to the Astronomical Society were efforts made to relieve practical astronomers in certain numerical calculations at once intricate and laborious. The first related to the occultations of fixed stars by the Moon; and the second to the arrangement of tables for the reduction of certain stars to their mean places at an assigned epoch. The first involves mainly geometrical considerations; but to handle the latter with any success, requires all the resources of a knowledge of some of the most intricate questions in astronomical dynamics.

From 1821 to 1823 he was associated with Mr. South in Blackman Street, Southwark, in the reobservation of the double stars discovered by his father. He had himself commenced the work as early as 1816, deeply interested in those marvellous movements of Sun around Sun which had been brought to light by the labours at Slough. He now resumed them in London with instruments in Mr. South's possession, described by Mr. Baily, the President of our Society in 1826, as "a princely collection, of exquisite workmanship, and considerable magnitude, such as have never yet fallen to the lot of a private individual." The result of their joint labours is printed in the Transactions of the Royal Society, and their importance and success were acknowledged by medals from that learned body, and subsequently from our own, and by the Lalande Medal of the French Institute. It is a matter of scientific interest to observe that a similar acknowledgment was at the same time made by our Society to Wilhelm Struve for the first-fruits of similar labours, undertaken with Fraunhofer's far-famed achromatic telescope at Dorpat. To this work Struve says he was fired by the noble example of William Herschel.

The conjoint labours of the two astronomers came to an end by the removal of South to the neighbourhood of Paris, in search of a clearer atmosphere than that which enveloped our own metropolis even half a century ago; the result was pretty much the same as that experienced subsequently by other observers, namely, that he would have been equally successful at home. Meanwhile, and after the termination of his travels on the Continent of Europe, Herschel resumed at Slough the dutiful but self-imposed and gigantic task of re-examining the double stars and nebulæ which through a long life had formed the solicitude of his illustrious father. It is interesting to read his own description of the instruments employed, he says,—

"The telescope with which the following observations were made is one of that construction which has been called the 'front-view.' The aperture, or clear polished surface of its mirror, is 18 inches, and its focal length 20 feet. It was constructed in the year 1820, under the joint superintendence of my father and myself, on the model of that used by him in his *Sweeps of the Heavens*, whose place it was intended to supply, the woodwork of

the latter being greatly decayed by age. At the same time a new speculum was cast, with a view to preserve the old one, the figure of which was remarkably fine for the most delicate observations." And then at a subsequent part of his *Introduction* he proceeds to say: "It will now be right to mention more particularly the modifications I have introduced into my father's system of sweeping, —modifications rendered necessary by the loss of my aunt, Miss Caroline Herschel's personal assistance, on whom the task of reading and registering the Polar Distance and Right Ascensions of objects, writing down the remarks and descriptions, warning the observer of expected stars, and finally reducing and calculating the whole, used invariably to devolve. Unsupported by such aid, I am under the necessity of recording the observations myself; an inconvenience of the worst kind, not only as it diminishes by at least one-half the number of the objects that can be taken, but because the frequent admission of extraneous light to the eye is fatal to observations of the fainter nebulæ."

These labours extended as far as a Sixth Catalogue, which was printed in the ninth volume of the *Memoirs of the Royal Astronomical Society* in 1835. Meanwhile observations of the nebulæ visible in these northern regions were proceeding steadily; but these were reserved for the *Transactions of the Royal Society*, with the exception of a most interesting and admirable monograph on the Nebulæ of *Orion* and *Andromeda*, which will be found in the second volume of our own. We would earnestly recommend those who are interested in the history and progress of science, and especially Astronomical science, to read the introduction to such memoirs as these of the two Herschels, and of other great Astronomers of half a century back, among many other cogent reasons, especially in order to know how deeply modern observers are indebted to the ingenuity of their predecessors. Through their persevering ingenuity we have been gradually provided with instruments and methods which save an amount of labour and of anxious manipulation which appears incredible when understood. The smooth automatic motion of the magnificent astronomical machines of modern days, leaving both hands at liberty for adjusting the exquisite micrometers provided by the great artists of our day, will be all the better appreciated if they will master and reflect on the comparatively clumsy, harassing, and laborious, though efficient, expedients necessarily adopted by the two Herschels. It seems indeed to be an inevitable law imposed on the achievement of all great work, and on all great discoveries, that they shall be completed under disadvantages. Neither Dalton nor Davy nor Wollaston nor Faraday luxuriated in the appliances at this day found in our physical laboratories.*

* In connexion with this, and with the amazing advances recently made in the delicate accuracy of modern mechanical engineering, we may here mention an anecdote not without its interest. Some time ago we ventured to assert that the above-mentioned improvements were mainly due to Mr. Babbage's attempts to complete his calculating machine, and we wrote to Mr. Babbage on the subject.

In 1827 we find John Herschel occupying the chair of the Royal Astronomical Society; and now commenced that series of presidential addresses, which we do not hesitate to say are unrivalled for instructive eloquence, masterly arrangement, and comprehensiveness of view. We shall here give one specimen, taken from the address which he delivered on presenting his friend, Baily, with the Society's medal for the completion of his superintendence of the Society's Catalogue of Stars. It would seem almost impossible for any imagination, however vivid, to clothe the description of so bare a thing as a catalogue of stars, with the amenities of human interest, and the graces of a poetic eloquence. Yet it will be seen that Herschel has accomplished this feat; and, probably, without the consciousness of attempt. He describes what, as an accomplished philosophical astronomer, he felt—and no doubt had often felt before. "If we ask to what end magnificent establishments are maintained by states and sovereigns, furnished with master-pieces of art, and placed under the direction of men of first-rate talent, and high-minded enthusiasm, sought out for those qualities among the foremost in the ranks of science: —if we demand *cui bono?* for what good a Bradley has toiled, or a Maskelyne, or a Piazzi worn out his venerable age in watching? the answer is, not to settle mere speculative points in the doctrine of the universe; not to cater for the pride of man, by refined inquiries into the remoter mysteries of nature,—to trace the path of our system through infinite space, or its history through past and future eternities. These indeed are noble ends, and which I am far from any thought of depreciating; the mind swells in their contemplation, and attains in their pursuit, an expansion and a hardihood which fit it for the boldest enterprise.—But the direct practical utility of such labours is fully worthy of their speculative grandeur. The stars are the land-marks of the universe; and amidst the endless and complicated fluctuations of our system, seem placed by its Creator as guides and records, not merely to elevate our minds by the contemplation of what is vast, but to teach us to direct our actions by reference to what is immutable in His works. It is, indeed, hardly possible to over-appreciate their value in this point of view. Every well-determined star, from the moment its place is registered, becomes to the astronomer, the geographer, the navigator, the surveyor,—a point of departure which can never deceive or fail him,—the same for ever and for all places, of a delicacy so extreme as to be a test for every instrument yet invented by man, yet equally adapted for the most ordinary purposes; as available for regulating a town clock, as for conducting a navy to the Indies; as effective for mapping down the intricacies of a petty barony, as for adjusting the boundaries of transatlantic empires. When once its place has been thoroughly ascertained and carefully recorded, the brazen circle, with which

His reply was, "You are quite right; it used to be said by the men in my workshop, Mr. Babbage made Clement, Clement made Whitworth, and Whitworth made the tools."

that useful work was done, may moulder, the marble pillar totter on its base, and the astronomer himself survive only in the gratitude of his posterity : but the record remains, and transfuses all its own exactness into every determination which takes it for a ground-work, giving to inferior instruments, nay even to temporary contrivances, and to the observations of a few weeks or days, all the precision attained originally at the cost of so much time, labour, and expense."

We enter now upon a summary of the labours, which this earnest philosopher prosecuted with undeviating diligence, during his sojourn at the Cape of Good Hope. We should have called this the most remarkable period of his life (and we have heard those who knew him best speak of it as the happiest), but, whether he is at Cambridge, or at Slough, or at Feldhausen, or at Collingwood, each period of that busy existence carries with it its own distinctive labours, and is full of its own philosophic interest.

The motives which impelled him to take this distant journey, cannot be better conveyed than in his own language, which we transcribe from the volume containing the results of his labours and his scientific musings in South Africa. He states that about the year 1825 he had commenced a re-examination of various observations which had occupied the greater part of his father's life; he then rearranged the whole, and communicated the results from time to time to the Royal, and Royal Astronomical Societies. He then goes on to say, "Having so far succeeded to my wish (the places of the objects thus determined proving on the whole satisfactory), and having by this practice acquired sufficient mastery of the instrument employed (a reflecting telescope of $18\frac{1}{4}$ inches clear aperture and 20 feet focus, on my father's construction), and of the delicate process of polishing the specula; being, moreover, strongly incited by the peculiar interest of the subject, and of the wonderful nature of the objects which presented themselves in the course of its prosecution, I resolved to attempt the completion of a survey of the whole surface of the heavens, and for this purpose to transport into the other hemisphere the same instrument which had been employed in this, so as to give a unity to the results of both portions of the survey, and to render them comparable with each other.

"Accordingly, having placed the instrument in question, as well as an equatoreally mounted achromatic telescope of 5 inches aperture and 7 feet focal length, by Tulley, which had served me for the measurement of double stars in England, together with such other astronomical apparatus as I possessed, in a fitting condition for work, and taking every precaution, by secure packing, to insure their secure arrival in an effective state, at their destination, they were conveyed (principally by water-carriage) to London, and there shipped on board the *Mount Stewart Elphinstone*, an East India Company's ship, in which, having taken passage for myself and family for the Cape of Good Hope, we

joined company at Portsmouth, and sailing thence on 13th November, 1833, arrived, by the blessing of Providence, safely in Table Bay on the 15th January, 1834." He then proceeds to explain the position of the residence he was fortunate enough to acquire by purchase, and adds that all preparations were "pushed forward with such effect, that, on the 22nd of February, I was enabled to gratify my curiosity by a view of *α Crucis*, the Nebula about *η Argûs*, and some other remarkable objects, in the 20-feet reflector; and on the night of the 5th of March to commence a regular course of sweeping."

The vast mass of scientific labour completed during the next four busy years at Feldhausen may be properly described by giving a very rapid summary of the principal contents of the volume of the *Cape Observations;* a work which we venture to say is not surpassed in varied interest or importance by any astronomical work in existence. It was not published until 1847, nine years after the author's return to England, for the very cogent reasons assigned by himself: "The whole of the observations, as well as the entire work of reducing, arranging, and preparing them for the press, has been executed by myself." Perhaps none but practical astronomers can form a true conception of the incredible amount of personal and tedious labour implied by these words. Nine years, indeed, would not have been sufficient to complete the task, had not the work been first planned with a careful sagacity, and then carried out with undeviating perseverance.

The first chapter of the volume, consisting of 164 quarto pages, records the history of his observations of the Southern Nebulæ and clusters of stars. They are then systematically arranged in a catalogue, containing the places of 1707 of these objects, all reduced to the epoch 1830, and each object bearing, in condensed literal symbols, a complete description. But this gives a very inadequate view of his labours among the Southern Nebulæ. He selects the most remarkable objects among them, delineates them with a scrupulous care, and then makes charts and catalogues of the numerous small stars in their neighbourhood, with the view of the future detection of any changes in these mysterious bodies. Completeness and utility are evidently the aims which direct and sustain his labours. His delineations and descriptions of the great Nebula of *Orion*, and of the region surrounding the remarkable star *η Argûs*, will long remain among the most remarkable of astronomical monographs; and the latter is at this moment, nearly thirty years after its publication, of singular importance, as serving to establish the present non-variableness in the form of the adjacent Nebula, which has become a subject of dispute. The labour and the thought expended upon these detached and selected objects, probably equals that required for the observation of all the other Nebulæ combined. In a minute portion of the heavens, scarcely exceeding twice the space occupied by the Moon's disk, there are recorded the places of no less than 1216 stars. A spangle viewed

at arm's length would eclipse the whole; yet he himself acknowledges it was the anxious work of several months.

These catalogues and charts are no sooner completed than he proceeds to discuss questions connected with them, and of the most absorbing interest. He inquires into the law of the distribution of these wonderful masses of glowing vapours, and these clusters of luminous suns. He thereby confirms his father's hypothesis that the Nebulæ are not irregularly scattered, and with no apparent law, hither and thither in the visible heavens, but are collected in a sort of canopy in the vertex or pole of that vast stratum of stars in which our Solar System finds its own position, buried in it, as he supposes, at a depth not greater than that of the average distance of an eleventh-magnitude star. These remarkable conclusions of the two Herschels are now being subjected to a re-examination by Mr. Proctor; but whatever the result may be, it is to the astounding industry and sagacity of the two Herschels alone, that so magnificent a conception has been entertained and brought into the cognizance of human thought.

The Nebulæ being at length dismissed, he proceeds to detail his observations of the double stars which had presented themselves during the sweeps for nebulæ. They are not dismissed until a regularly arranged catalogue of all that he had observed was completed, and ready for comparison by any subsequent astronomer. But there was a point of view which possessed for Herschel a peculiar charm. His father, half a century before, had commenced the observation of these singular objects—singular from their optical proximity, and still more so from the contrast of the colours of so many of these binary combinations. The motive which had invited the elder Herschel to the work, was a well-grounded hope that they might lead to the discovery of the distances of many stars from the Earth; this was the one great element which was wanting for the completion of his magnificent conception of the distribution of the universe of stars. He failed in this, but his failure herein was at length accompanied by the discovery that many of these stars moved round each other, and were to each other as revolving suns. John Herschel also had invented an elegant and practicable method of determining the forms of these orbits, and the periods which these suns take to complete their revolutions. In particular he had calculated the orbits of the two stars which form the combination *γ Virginis*, and he had the crowning satisfaction of seeing what he terms their *perihelion appulse;* he saw the two stars (as he had predicted) so close together, that his telescope was unable to detect their duality. Such visible reward of honest labour is not always accorded to the labourer. At the same time Herschel took the opportunity of improving certain imperfections which still adhered to his method of treatment. The period of revolution he ascertained to be approximately 182 years, not greatly exceeding the period of the planet *Neptune* round our Sun. If *Neptune* had been greatly larger than he is, would he have now shone by other than a reflected

light? And if so, what sort of dynamical problem would the perturbation of our Earth and Moon have presented to the mathematical Astronomer?

In the course of the chapter which contains the catalogue and investigations of the double stars, Herschel makes one of those characteristic remarks which, while they enliven the narrative serve for us a still higher purpose; they exhibit the perseverance and the self-denial of the observer. He is referring to certain small regions of the heavens, which are barren of interesting objects, and he observes that it was well for himself to enter some remarks in his note-book "for the homely, but useful purpose of avoiding sleep,* and that not unattended with the probability of broken bones." The well-known picture of the mounting of the Herschelian Telescope, will recur to the memory of our readers, and they will readily imagine that a fall from the observer's subaërial stage was by no means impossible, and assuredly dangerous if it occurred. It is by the path of labour and self-denial, that to great men is accorded the meed of immortality by their fellows.

The double stars and their stately revolutions and lustrous colours dismissed, in the next chapter he proceeds to describe the methods by which the magnitudes, or rather the relative brightness of the stars, may be observed and catalogued. In the library of the Astronomical Society there are preserved certain sheets of paper, on which he had marked the allineations and magnitudes of all the stars visible to his naked eye in the Northern hemisphere. The labour is less than it appears to be, owing to the comparatively small number of stars visible to unaided vision at one place; John Herschel accomplished it for the stars in both hemispheres. And if the detail of such occupation shall perchance raise the question whether such labour is misplaced for any man, and still more so for such a man as Herschel, let us listen to his own account of it.

"The subject," he says, "is one of the utmost physical interest. The grand phenomena of geology afford, as it seems to me, the highest presumptive evidence of changes in the *general* climate of our globe. I cannot otherwise understand alternations of heat and cold, so extensive at one epoch as to have clothed high Northern latitudes with a more than tropical luxuriance of vegetation; at another to have buried vast tracts of Middle Europe, now enjoying a genial climate, and smiling with fertility, under

* John Stone, the worthy mechanic who assisted Herschel at the Cape, and of whom he makes honourable mention in the preface to his book, informed the writer that on one occasion when Herschel was observing Halley's comet, the astronomer *did* actually fall asleep. It was Stone's office to *say* nothing, but to turn the telescope. He kept at his post, but wondered at his master's long silence, and in due time he turned the telescope in the direction of the Table Mountain, Halley's Comet being now behind it; on a sudden Herschel awoke, and the next moment looking into the telescope, exclaimed, "Stone! Stone! where *has* the Comet gone to?"

a glacier crust of enormous thickness. Such changes seem to point to some cause more powerful than the mere local distribution of land and water (according to Mr. Lyell's views) can well be supposed to have been. In the slow secular variations of our supply of light and heat from the Sun, which in the immensity of time past may have gone to any extent, and succeeded each other in any order, without violating the analogy of sidereal phenomena which we know to have taken place, we have a cause, not indeed established as a fact, but readily admissible as something beyond a bare possibility, fully adequate to the utmost requirements of geology. A change of half a magnitude in the lustre of the Sun, regarded as a fixed star, spread over successive geological epochs, —now progressive, now receding, now stationary, according to the evidence of warmer or colder general temperature which geological research has disclosed, or may hereafter reveal,—is what no Astronomer would now hesitate to admit as in itself a perfectly reasonable and not improbable supposition. Such a supposition has assuredly far less of extravagance about it than the idea that the Sun, by its own proper motion, may, in indefinite ages past, have traversed regions so crowded with stars as to affect the climate of our planet by the influence of their radiations."

Such, then, was one of the reasons which actuated both the Herschels in their midnight survey of the stars; and we may, in passing, mention another instance of J. Herschel's methodical diligence in this, that he had proposed to himself to devote the enforced leisure of the voyage home by sea, to the completion of these comparisons of stellar brightnesses, and so carry on the sequence of these relations to the stars of the north, not visible in South Africa. Bad weather, however, interfered with the consecutiveness of the work, and two nights only were favourable to his design. He says:

"It was my earnest wish to have carried on these comparisons during the whole of our homeward voyage (the observations being easily made on ship-board) so as to interweave in sequences sufficiently numerous and extensive, at least all the most conspicuous stars of both hemispheres; but in this I was disappointed, at least to that extent: as a totally overcast state of the sky prevailed from the day of our departure from Table Bay, until we reached nearly the latitude of St. Helena, with the exception of a single fine night on the Equator, on the 28th of March, 1838, advantage of which was taken to procure a short sequence, and several valuable comparisons of Southern stars with stars of equal or nearly equal lustre in good situations for European observations. But, with this exception, no other available opportunity occurred till the 14th and 15th of April, when two sequences were observed in latitude 17° and 18° north; but in these the more Southern stars were already too low for fair comparison."

After the discussion of the magnitudes and distribution of the stars in the Southern hemisphere, there comes a chapter upon Halley's Comet, containing many interesting observations on the

physical features and dynamical action of cometary matter. He lived long enough to learn how great a stride has been made in our knowledge of such things, by the combined labours of such men as Kirchhoff, Huggins, and Schiaparelli; nevertheless, Herschel's discussion is replete with instruction. Similar remarks may be made with respect to his discussion of Sun-spots, and this is rendered all the more valuable from the impetus which it gave to Mr. De La Rue, Prof. Selwyn, and others, whereby they were induced to commence their invaluable labours on the Sun's autography. It is in this chapter that he suggests that form of first-surface reflecting eye-piece, which has completely revolutionised the method of viewing the Sun's photosphere.

Such is an outline, and a bare and imperfect outline, of the contents of this impressive volume. In perusing it we can with difficulty persuade ourselves that in reality it comprises the chief labours of four years only of a philosopher's life. Happily John Herschel, in this respect of devoted and intelligent labour, does not stand alone among the other great Astronomers of his age. The world hears but little of them at the time; they neither strive nor cry in the streets, but their labours remain as imperishable as the genius which inspires them.

As was natural and honourable to all concerned, he was greeted with enthusiasm on his return to England. There is something contagious in a great example, and one of Herschel's rewards consisted in this, that he inspired others with a zeal kindred to his own. In due time another Astronomer, Mr. Lassell, at his own expense, and with a more magnificent instrument, constructed like Herschel's with his own hands, expatriated himself and his family to Malta for three years, under the hope of adding, if possible, to the discoveries of Herschel. In this he succeeded. Herschel must have had multitudinous thoughts pressing on his mind when, in 1849, he placed the Gold Medal of the Astronomical Society in Mr. Lassell's hands, saying, that "the simple facts are these: Mr. Lassell cast his own mirror (24 inches in diameter), polished it by machinery of his own contrivance, mounted it equatoreally in his own fashion, and placed it in an observatory of his own engineering. With this instrument he discovered the satellite of *Neptune*, the eighth satellite of *Saturn*, and reobserved the satellites of *Uranus*."* He spoke, moreover, of Mr. Lassell as one of those, "who, by their personal example, press forward the advent of that higher phase of civilisation which some fancy may see not indistinctly dawning around them; a civilisation founded on the general and practical recognition of the superiority of the pleasures of mind over those of sense; a civilisation which may dispense with luxury and splendour, but not with the continual and rapid progress of know-

* Mr. Lassell did more than this subsequently at Malta. He in reality discovered two satellites of *Uranus*, and rendered it exceedingly probable that four satellites only have yet been seen, instead of the six suspected by the elder Herschel.

ledge in science and excellence in art." In mentioning Mr. Lassell, we gladly also recall to our memory similar scarcely less important labours of Mr. De La Rue.

In 1830, appeared his well-known *Preliminary Discourse on the Study of Natural Philosophy;* this was followed by a similar volume on Astronomy, both being published in *Lardner's Cyclopedia*. The latter, in 1849, was superseded by his larger and more important *Outlines of Astronomy*. No comment of ours is needful on these remarkable books ; any one of the three would have sufficed to establish the scientific reputation of an ordinary writer. The first of them may be regarded as having contributed in no small measure to the fostering of that taste for scientific pursuits which has lately become a characteristic of our age. There is a sweet and dignified persuasion animating the volume, which, to a reader with a well-constituted mind, is irresistible. The last of the three, like the first, has become a classical work in our language ; and has been the means of directing many hundreds of persons to the pursuit of a science which he knew to be inferior to none in its humanizing tendencies. These books are nothing short of a benefaction to mankind.

There are some passages in the former of these volumes which are displeasing to the disciples or admirers of Comte. Herschel, in all loyalty to his own science, had exposed certain shallow conceptions and scientific blunders of that talented but singular man ; and he had no sympathy with his philosophy. He had a profound belief in causation as distinct from sequence, and in a great First Cause, and in many passages of his writings he had traced the evidence of a Personal Will in nature. Hence Herschel was not forgiven by a certain class of metaphysical writers. They were his sole literary antagonists ; personal enemies he had none.

His two treatises on *Light* and *Sound* were published in the *Encyclopedia Metropolitana* about the year 1830. The former has probably been read by every competent mathematician in the country, and every reader will have felt the charm of the half-suppressed enthusiasm which has carried him along. It contains the results of his own experimental investigations on the action of certain crystals on polarized light,—plagiedral quartz, apophyllite, Rochelle-salt, for instance,—results which have been confirmed and generalized since his early days. It would be a national advantage in the education of our higher classes of mathematical students if authors would take a leaf out of Herschel's books, and clothe the dry bones of their writings with a little judicious historical or experimental illustration.

But there is another volume of his not so widely known to the public as either of the former works. In this volume he collected many of his addresses to public bodies,—in particular, to the Royal Astronomical Society, and to the British Association. It was published in 1857 by Longmans. We venture to say it is here that the great philosopher is seen in his happiest and most

instructive mood, for these addresses contain the outpourings of a man walking at liberty among sympathizing associates, in his own home, and enamoured with its interest and beauties. Whether it is the affectionate yet wise earnestness with which he dilates on the comprehensive labours of a Bessel, or on the ponderous analysis of a Plana, or on the intelligent and loyal devotion of his friend, Baily, to the science and the society of his adoption, all teem with historical associations and pregnant suggestions which will richly reward the student who will devote his hours to their perusal.

In this volume, his review of *Quetelet on Probabilities* is reprinted ; it favourably exhibits Herschel in the guise of a social philosopher, and it contains by far the clearest popular exposition of the principle of Least Squares that has yet appeared. An able and very recent writer on this difficult subject in the *Transactions of the Royal Society*, ascribes to this demonstration a character higher than popular.*

The volume terminates with a collection of certain of his efforts in fugitive poetry. For John Herschel was a poet in a high sense, and of science he was emphatically *the* poet. Without imagination no man can become a truly great philosopher, and still less a truly great writer ; and Herschel was both ; and hence with him, as with many other of our ablest mathematicians, versifying became a solace and a recreation from severer work. There are passages in some of these little poems, and there are lines in his more formal translation of the *Iliad*, published at a much later period, which plainly indicate that had he chosen to make poetry the occupation of his life, he must have occupied a conspicuous place among the poets of his age. His sonnet on Sir William Hamilton in Ely Cathedral, and his verses entitled "A Dream which was not all a Dream," and which furnished one of his solaces in his latest hours, are sufficient evidence of the estimate we have made. Nevertheless it seems astonishing that a man with so cultivated an ear for music as he possessed, should have encumbered himself with the impossibilities of English hexameters, not feeling that the sweet and varied cadence of the Homeric metre cannot be transfused into our less flexible language. It is here, perhaps, that we may mention, as a pleasing trait of the

* In this volume is included a very able and interesting review of Mrs. Somerville's *Mechanism of the Heavens*, in which he reverts to what occurred at Cambridge during the transition of the mathematical studies of the place, to which we have referred in page 125 of this memoir. He says:—"Students at our universities, fettered by no prejudices, entangled by no habits, and excited by the ardour and emulation of youth, had heard of the existence of masses of knowledge from which they were debarred by the mere accident of position. These required no more. The prestige which magnifies what is unknown, and the attractions inherent in what is forbidden, coincided in their impulse. The books were procured, and read, and produced their natural effects. The brows of many a Cambridge Moderator were elevated, half in ire, half in admiration, at the unusual answers which began to appear in examination papers. Even Moderators are not made of impenetrable stuff: their souls were touched, though fenced with seven-fold Jacquier, and tough bull-hide of Vince and Wood."

habits of his life, that one of his last letters was written to his friend Sir Thomas Maclear at the Cape, and contained some popular nursery rhymes translated into Latin verse.

It is instructive to observe what sort of work Sir John Herschel reserved as the occupation of his old age. He could hardly expect at the age of seventy to make any positive advances in the science which had already occupied so many years of an active life. Besides the *Translation of the Iliad*, already referred to, he busied himself in arranging his own and his father's observations in a complete and collected form; he wrote, also, several very striking articles on some of the more popular aspects of science, in *Good Words*. These and a few other lectures and addresses he collected in a single volume, bearing the title *Familiar Lectures*, — a little book, but eminently calculated to diffuse a taste for the study of the forces in constant operation around us; and in many of its paragraphs so suggestive as to arrest the attention even of those who are proficients in the subjects on which he writes. We entertain no doubt that the motive which impelled him to write this book was that which he had so well expressed in his address to the Educational Institute in South Africa, and which we have already quoted, namely, the importance which he attached to the diffusion of scientific knowledge, as a civilising agent, among the great masses of the people; for it was a characteristic of Herschel, that what he wrote, he wrote with settled purpose long entertained, and we may here be permitted to record an instance of this predetermination. We had occasion, a few years ago, to write to him to request a reference to some of the many passages in his writings wherein he had referred to the evidences of the action of a Personal Will in nature. The immediate reply was a little manuscript containing the transcription of all the passages which had been the object of our search, and which he had himself collected for his own purposes long before. A week or two before his death he again wrote with some solicitude on the same subject. This conscious and pervading intention of his life, is rendered still more evident by the state of completeness in which he left the record of all the most important undertakings of his scientific career. Thus, seven years before his removal, and therefore in his seventy-second year, he presented the Royal Society with a magnificent catalogue of all the nebulæ that had been recognised up to the date of its completion, whether observed by himself, by his father, or by any other astronomer.

Hence, again, during the last few years of his life he busied himself in doing what perhaps no other man could at any time have done so well, namely, in arranging a catalogue of all the double stars that were known to exist up to the most recent date. This catalogue was intended to contain what may be termed the natural history of every such star; that is to say, everything that had been observed or known concerning it. This grand and gigantic work was arranged and completed just

before his death, so far as the catalogue itself is concerned. It contains about 10,000 double stars, all arranged in Right Ascension and Polar Distance, and the entire history of about 5000 of these stars is completed. He bequeathed this precious monument of his intelligent labour to the Astronomical Society; and we, to whom the editing is confided, shall most assuredly write with a loving and a truthful pen, on the last page of the volume the motto which in life pleased him so well, "Cœlis Exploratis."

John Herschel met with an amount of public recognition unusual in England. He might have been, had he wished it, President of the Royal Society, and he four times accepted the chair of the Royal Astronomical Society; the Society pleased him in its unpretendingness and solid work. He was appointed to the Mastership of the Mint, as Newton had been before him; but he fell upon the evil days of a reform in the place, and his sensitiveness was, in consequence, put to many a severe trial. He held the office for five years. At an early period of his life he received the recognition of a Hanoverian Knighthood; and at a later period the heritable title of a Baronetcy was accorded to him and his family. The scant measure of even this reward, raises difficult questions in the mind, and great searchings of heart. Naturally he was a member of almost every important learned society in either hemisphere. The French Institute honoured themselves by at last electing him a Foreign Member of their body. He married Margaret Brodie, daughter of Dr. Stewart, in 1829: she and a numerous family survive him. Two of his sons are already very favourably known in the realm of science, and their father lived to see one of them selected by the Council for election to the Fellowship of the Royal Society. It would have been a gratification to him, had he lived long enough, to see the other appointed to a very important Professorship in the North of England.

What was Herschel's true place in the philosophy and among the other great lights of his age, cannot be accurately fixed until his own generation shall have entirely passed away; the partialities and the prejudices of contemporaneous life, unavoidably warp and incapacitate the judgment, just as too close a proximity to a mass or a multitude is unfavourable to a correct appreciation of its proportions. The judgment passed by the able writer of his obituary notice in the *Proceedings* of the Royal Society, is naturally influenced by an affectionate remembrance of his friend, nevertheless it is not unsupported by less partial critics: he says, "British science has sustained a loss greater than any which it has suffered since the death of Newton." Long ago a somewhat similar estimate of his powers, both intellectual and moral, was made by one of the most competent among foreign *savans*, the celebrated Biot, to the effect that if he did not love John Herschel so much, he should not hesitate to say he was the ablest and most worthy of the successors of Laplace. But there is no need to make the comparison, his works are with us.

It is not for us to lift the veil which screens the sanctities of domestic life; but in the portrait we have sketched with a conscious feebleness, the reader will see what are the lineaments of a great Philosopher in his public relations; the mode, the aims, the hopes, the features, of his outer life. The noble example, the inevitable stimulativeness of such a life, are priceless. Though not lifting the veil of his home, we may say of him, that he there realised just what the reader would picture and would wish that life to be. He was a firm and a most active friend; he had no jealousies; he avoided all scientific feuds; he gladly accorded a helping hand to those who consulted him in scientific difficulties; he never discouraged, and still less disparaged, men younger than or inferior to himself; he was pleased with the appreciation of his works, but this was not an object of his solicitude; we quote the words of a discriminating critic, for they are not words of extravagance, when we say of him, that "his was a life full of the serenity of the sage, and the docile innocence of a child." Happy the pursuits that can lead to such results.

Herschel's whole life, like the lives of Newton and Faraday, confutes the assertion, and ought to remove the suspicion, that a profound study of Nature is unfavourable to a sincere acceptance of the Christian Faith.

Surrounded by an affectionate family, of which he had ever been the pride, the guide, and the life, John Herschel died as he had lived in the unostentatious exercise of a devout, yet simple, faith. The recollection of the long procession of his many friends, numbering among them some of the brightest and choicest intellects of his countrymen, still dwells vividly in our minds: what was mortal of him, we laid in Westminster Abbey, close by the side of Newton. The inscription on his monument is a happy but condensed expression, of the most deeply cherished thoughts of his life:—

JOANNES HERSCHEL
GULIELMI HERSCHEL
NATU OPERA FAMA
FILIUS UNICUS
"CŒLIS EXPLORATIS"
HIC PROPE NEWTONUM
REQUIESCIT
GENERATIO ET GENERATIO
MIRABILIA DEI NARRABUNT
PSALM CXLV. 4, 5.
VIXIT LXXIX. ANNOS
OBIIT UNDECIMO DIE MAII
A.D. MDCCCLXXI. [C. P.]

Sir Roderick Impey Murchison, Bart. K.C.B., was born on February 19, 1792, at Tarradale, a small estate in the possession of his father, in eastern Ross-shire, N.B. He was the

eldest son of Mr. Kenneth Murchison, and of Barbara, daughter of the late Mr. Kenneth Mackenzie, of Fairburn, in the same county. At a very early age he left Scotland for Dorsetshire, and, excepting a short period when he resided with his mother in Edinburgh, his boyhood was principally spent in England, where he received his education. He was first placed in the grammar-school attached to the Cathedral of Durham, but exhibiting a strong inclination for the military profession he was removed to the Royal Military College at Great Marlow. He subsequently attended, for a few months only, the classes at the Edinburgh University, but his studies were interrupted by receiving, in 1807, a commission in the army, he at the time being just fifteen years of age. In 1808 he joined the forces in the Peninsula, under Sir Arthur Wellesley, first as ensign in the 36th Regiment of Foot, and afterwards serving either on the staff of his uncle, Sir Alexander Mackenzie, or as Captain in the 6th Dragoons. He shared the varied fortunes of the division of the army to which he was attached, having fought in three general actions, Roliça, Vimiera—where he carried the colours of his regiment—and Corunna, including all the hardships and dangers attending the memorable retreat under Sir John Moore. Returning to England, Captain Murchison married, in 1815, Charlotte, only daughter of the late General Francis Hugonin, and thus concluded, as he was frequently heard to remark, the military episode of his life.

Murchison was, however, of far too active a disposition to remain in a state of idleness at this time of life, so in the absence of better employment the exuberance of his spirits found vent in the excitement of the chase. Fox-hunting became one of his chief pastimes, and he entered into its pleasures with all the energy at his command. He might have continued a popular, sporting, country gentleman, but for the influence of Mrs. Murchison, a lady possessing a considerable knowledge of conchology and a fondness for natural history pursuits. Through her he received his first encouragements to pursue the study of geological science. It happened, also, that about this time he accidentally met Sir Humphry Davy at the house of Mr. Morritt of Rokeby. Sir Humphry, seeing too much practical sense in young Murchison for a mere fox-hunter, advised him to attend the lectures on physical science at the Royal Institution. He not only attended the lectures, but he followed them up by a series of practical experiments on his own account. To do this in a satisfactory manner he placed himself under the private instruction of the late Mr. Richard Phillips, F.R.S. From this date the scientific career of Murchison may be said to have commenced.

His first paper was presented to the Geological Society in 1825, entitled *A Geological sketch of the north-western extremity of Sussex, and the adjacent parts of Hampshire and Surrey.* It is published in Volume II. of the *Transactions* of that Society.

Murchison was now thirty-three years old, and henceforth devoted his whole energies to the pursuit of his adopted science. Year after year we find him occupied in the personal examination of the geological formations of various districts in Great Britain and on the Continent, beginning in 1826 with the coal strata in Sutherlandshire, which he demonstrated to be a branch of the Oolite series. In 1827 he again visited the Highlands in company with the now venerable Professor Adam Sedgwick, when they succeeded in proving that the primary sandstone of M'Culloch was really nothing more than the true old red sandstone, now also called "Devonian." In the following year, accompanied by Mr. (now Sir Charles) Lyell, he examined the volcanic rocks of Auvergne and the tertiary strata of Southern France. In this manner, first in one country and then in another, he continued his observations in the field, adding fact upon fact, all of which are recorded in the *Transactions* of the Geological Society and in other scientific publications. In the catalogue of scientific papers published by the Royal Society, Sir Roderick Murchison is credited with 111 separate papers, and twenty-six published in conjunction with other authors. To all the labour required in the preparation of such a mass of work must be added that necessarily involved in the writing of the valuable treatises, published separately — *The Silurian System — On the Geology of Russia* — and the successive editions of *Siluria*. The last-named is perhaps the best known of his writings, and, more than any other of his works, has helped to lay the foundation of Sir Roderick's fame. It is entitled *Siluria; or the History of the oldest known Rocks containing organic Remains, with a brief Sketch of the Distribution of Gold over the Earth;* and includes a general view of the structure of the Earth's crust, but more particularly of the more ancient series of strata, of which the Silurian system is the lowest; it also includes a summary of the author's opinions with respect to geological science, especially on those matters where he has differed from his distinguished friends, Professor Sedgwick and Sir Charles Lyell.

As a geographer, Sir Roderick Murchison stood in the foremost rank. The great influence he held over the proceedings of the Royal Geographical Society could be perceived in a moment by the most casual visitor to its ordinary meetings. No one took a greater interest in the progress of physical geography than he did, down to the last few days preceding his death. His annual addresses at the anniversary meetings of the Society always contained an excellent epitome of geographical discovery during the year. His kind and courteous manners, coupled with the zeal and energy with which, as President, he supported the cause and personal well-being of travellers, both before and after their journeys, made him at once their trusted counsellor and friend. His name is thus known to all the civilised world as the chivalrous defender of such men as Livingstone, Speke, Du Chaillu, and others, against the adverse criticisms of some of their fellow-geographers.

With the attention of Sir Roderick so engrossed in geological and geographical pursuits, he still found time to interest himself in some of the recent great discoveries of observational astronomy, especially of those relating to the physical constitution of the solar photosphere and corona. He, however, never took any active part in the promotion of astronomical research, for he wisely left to others, more qualified than himself, the practical part of our science. But in one important branch he has done good service. He took every opportunity of impressing upon travellers the advantages to be derived from the frequent determinations of the absolute longitudes and latitudes in unexplored regions by astronomical observations. He was therefore always anxious that travellers, before leaving England, should make themselves acquainted with the practical use of the sextant and other portable instruments. Through his recommendation, also, the accumulated observations of lunar distances, meridional altitudes, temperatures of the boiling point of water, &c., made by Captain Speke, M. Du Chaillu, and other African travellers, were placed under the care of a professional astronomer, in order that they might be reduced by the use of the most approved astronomical methods. In this manner the geographical positions of several important points in the interior of Africa have been satisfactorily determined. Sir Roderick also showed his interest in our Society, and in astronomy, by becoming, in 1850, one of our Fellows.

On the death of Sir Henry De la Beche, in 1855, Sir Roderick Murchison was chosen to succeed that eminent geologist as Director of the Museum of Practical Geology in Jermyn Street, and as Director-General of the Geological Survey of England. It is not, however, necessary in this brief notice to enumerate more than a selection of the honours, royal and academic, which have been conferred on Sir Roderick in recognition of his scientific labours. By his own sovereign he was created a Knight Bachelor in 1846, a K.C.B. in 1863, and finally, a Baronet in 1866. He also received numerous foreign orders of distinction, including the Grand Cross of St. Anne, and of St. Stanislaus of Russia, and the dignity of Grand Officer of the Order of the Crown of Italy. It is almost needless to add that the Universities of Oxford, Cambridge, and Dublin, recognised his researches in science by the bestowal on him of their honorary degrees. In 1826, he was chosen a Fellow of the Royal Society, and subsequently became a member of the Council and a Vice-President. He was one of the founders of the Royal Geographical Society, and was first elected its President in 1843. He was re-elected at intervals up to 1862, since which year, till May 1871, he, by the general consent of the Society, remained in office. He also served as Secretary and President of the Geological Society. In addition to the numerous English and Foreign Societies of which he was an honorary member, Sir Roderick was also a Trustee of the British Museum, the Hunterian Museum, and of the British Association for the Advancement of Science. He received the

Copley Medal from the Royal Society, the Prix Cuvier from the French Institute, the Brisbane Medal from the Royal Society of Edinburgh, the Wollaston Medal, and other honours of the same kind.

In 1869, Sir Roderick sustained a great loss by the death of Lady Murchison, his companion of more than half a century. The first visible sign of his own decay manifested itself in an attack of paralysis in the latter part of 1870. He was in a dangerous condition for some time, and he remained afterwards in a more or less delicate state of health. However, he was able occasionally to appear in public; but he was never thoroughly himself again, and was obliged to delegate to others the duty of Chairman at the meetings of the Royal Geographical Society. Two months before his death he was seized with loss of speech, accompanied with difficulty in swallowing. These unfavourable symptoms gradually subsided, and his general health appeared to be restored to its usual state. But on Thursday, October 19, he caught a cold during a drive, which subsequently resolved itself into bronchitis. His constitution was not sufficiently strong to withstand this sudden attack, and he quietly sank under its influence. He passed peacefully away on the evening of Sunday, October 22, 1871, in the eightieth year of his age.

"Such has been the praiseworthy life of this illustrious man," remarks a writer in the *Athenæum;* "and while his fellow-countrymen have long since pointed out with pride to the stranger the house where Murchison was born, there are mountains and rivers in distant lands which shall tell out his fame to future ages in tones far louder than could ever re-echo from the vaults of Westminster Abbey."

William Rutherford, LL.D. was for many years one of the mathematical masters at the Royal Military Academy, Woolwich, and one always popular with his pupils. He was a mathematician of no mean rank, and his name is well known as the author of several mathematical pamphlets; one of which, on the solution of spherical triangles, is particularly worthy of notice. Dr. Rutherford was also a regular correspondent, both as proposer and solver of problems, to the Mathematical Section of the *Lady and Gentleman's Diary*, and his successful solutions of some of the most difficult questions gained him considerable notice among the readers of that once popular annual. He delighted in what he used to call a "very pretty problem," that is, in some question involving a delicate mathematical analysis; and of late years, when he was what he called "an idle man," nothing pleased him more than to have submitted to him some question which, perhaps, might require a week's work before a solution was arrived at.

Dr. Rutherford had great skill as an instructor, his explanations being remarkable for their clearness. He also impressed on his pupils the necessity of their treating the study of mathematics

as a means to an end, and not of looking on it as a subject by itself. Thus all his teaching was of a most practical character, and his mathematical examinations consisted of problems likely to occur to officers of the scientific branches of the army. He was of a quiet disposition, and was ever ready to give any aid to those who desired assistance from his knowledge and experience.

The Council of this Society had the advantage of the experience of Dr. Rutherford, as one of its members, during the interval between 1844 and 1857, and he served the office of Honorary Secretary in the two years 1845–6. He does not appear to have contributed to our *Transactions*, although he was well versed both in the theoretical and practical branches of astronomy. He was, however, always greatly interested in the investigations of some of his friends, and also in the principal subjects which occupied the attention of the Society during the time when he was an active member of the Council.

Dr. Rutherford retired from his office in the Royal Military Academy about eight years ago, after a very long service, and continued in the enjoyment of his usual good health until a few months preceding his death. He died at his residence, Maryon Road, Charlton, on the 16th of September, 1871, at the age of seventy-three.

The Rev. Thomas William Weare was the eldest son of the late Colonel Thomas Weare, K.H., Aide-de-camp to the Queen, and was born on November 2, 1813. He graduated at Christ Church, Oxford, in 1836. Subsequently to this he became Second Master of Westminster School, whence he retired in 1861. It was during the period of the tenure of this office that he was elected to the Fellowship of our Society, such election taking place on June 12, 1857. At this period, and up to the time of his quitting London in 1861, he was an occasional visitor at our Meetings, but ceased after this to attend them. His last appearance among us was on February 11, 1870, on the occasion of the fiftieth anniversary of the Society. He was appointed Rector of Isfield, in Sussex, in 1867; but mainly resided at his seat, Hampton House, in Herefordshire, for which county he was a Magistrate. He died at Speen, in Berkshire, on February 24, 1871.

Proceedings of Various Observatories.

Royal Observatory, Greenwich.

The only change in the usual course of observations during the past year has been the substitution of the Water-Telescope for the Reflex Zenith-tube in the spring and autumn observations of γ *Draconis*.

The state of the reductions is highly satisfactory, the greater

portion of the MS. for 1871 being already in the printer's hands, while the printing is in a more advanced stage than usual, as the whole of the Volume for 1870 has been printed off.

A well-marked discordance between the zenith-points deduced from the Nadir-observation, and those from stars observed by reflection with the Transit-Circle, has led to the application of a correction of $-0''\cdot82$ to the former. This naturally threw suspicion on the corrections for errors of graduation, in consequence of which a new determination of these errors for every 5° has been made, but no change in the circle-readings can be traced with any degree of certainty. It may be remarked that the discordance alluded to changed its sign with the flexure and R—D correction when the cube was pierced, being then hardly sensible; it has since gradually increased to its present value, at which it has now remained constant for more than a year.

The flexure of the Transit-Circle has been re-determined, and appears to be smaller by $0''\cdot25$ than the value previously adopted; a re-examination of the pivots agrees with former measures in the satisfactory conclusion that there is no sensible error of form.

Great attention has been given to the phenomena of *Jupiter's* satellites, more especially those of the third and fourth, which have been observed on almost every occasion when the weather permitted, though in many cases interfering seriously with the meridional observations. The results have been laid before the Society.

A close scrutiny of *Venus* with the great Equatoreal under favourable atmospheric conditions has failed to establish the existence of any decided markings on her disk or notches in her limb.

For a short period Encke's Comet was bright enough to be observed with the Transit-Circle, and its place was thus determined on several nights. The appearance of this object in the great Equatoreal is shown in a drawing made by Mr. Carpenter and exhibited to the Society. A woodcut taken from this drawing will be found in the *Monthly Notices*.

The uncertainty in the determination of fundamental R.A. arising from irregularity of clock-rate has been reduced to an inappreciable quantity by the substitution of a new and improved clock for the Transit-Clock Hardy. The new clock is placed in the Magnetic Basement, which, for other purposes, is maintained at a temperature as nearly uniform as possible, and this, no doubt, is an important element in the success of the clock. The chief peculiarities of construction of this Normal Sidereal Clock (the work of Messrs. Dent and Co.) are in the escapement and in the pendulum; the former is similar to the detached escapement used for chronometers and which has been already applied successfully to clocks at Greenwich; the latter, of the same form as that adopted for the Westminster clock, may be briefly described as follows:—A steel rod supports a zinc tube from which an exterior steel tube is suspended, carrying at its lower extremity

a leaden bob attached at its centre of gravity. Thus the expansion of the zinc tube compensates those of the steel rod and tube, the coefficient for zinc being, as is well known, nearly three times that for steel. This construction has also been applied with great success to the principal clocks intended for the Transit of *Venus* expeditions. In the Normal Sidereal clock there is also a very delicate means of making the final adjustment for compensation, but no necessity has yet arisen for trying this. The very slight changes of rate observed in the clock appear to take place very gradually and to have no connexion with temperature. As yet there are hardly sufficient data to establish their dependence on atmospheric pressure; but it seems that every considerable rise or fall of the barometer is accompanied by a corresponding increase or decrease of the losing rate.

Radcliffe Observatory, Oxford.

No change worth mentioning has taken place in the personal establishment or in the operations of the Radcliffe Observatory during the past year. The amount of work which has been performed both in the astronomical and the meteorological departments is nearly the same as that of the preceding year, and the reductions are kept up to almost the same state of forwardness, though, with every possible exertion, it is found impossible to gain much advance, either in the reductions or the printing. The greater portion of the astronomical part of the volume for 1869 is printed; and it is hoped that a few copies of the Catalogue of Stars for that year, amounting in number to nearly 1500, will be ready in a very short time. During that year, and those which have followed it, great attention has been paid to daylight observations of stars, and it may be mentioned that the rate of the transit-clock (since a little more mercury was put into the cylinders in 1868) has been exceedingly uniform. There is no difference throughout the year which can be attributed to temperature; and the slight deviations from uniformity, which are generally not of the nature of bad going or casual irregularity, afford scope for some interesting speculations.

It may be considered now that the materials for the Third Radcliffe catalogue are complete, and Mr. Main purposes to take in hand the compilation of it as soon as it is possible, with due regard to the progress of ordinary work, combining the observations of all stars from 1862 to 1871, both years inclusive. The weather during a great portion of the year has not been favourable to observations with the Heliometer, though a considerable number of double stars have been observed in the short intervals of fine weather. It may finally be mentioned that, commencing with October last, thirteen occultations of stars by the Moon have been observed, the greater number being at very low

altitudes, and therefore being available for the correction of the Moon's parallax.

Cambridge Observatory.

The new Transit Circle has been chiefly employed in determining the places of small stars in the zone lying between 25° and 30° of North Declination, a work which has been undertaken by this Observatory with the view of assisting in carrying out the plan formed by the German Astronomical Society for observing all the stars, to the ninth magnitude inclusive, contained in Argelander's *Durchmusterung des nördlichen Himmels.*

Upwards of 4,500 of these stars have been observed, and their true North Polar Distances accurately calculated.

All the instrumental and clock corrections have been obtained, and are ready to be applied for finding the Right Ascensions, as soon as the reductions to the centre wire, now in progress, are completed. These observations were taken with the instrument clamped in a fixed position, the bisections being made by means of the micrometer, and each star was observed at three of the vertical wires. In this way the stars within a range of about 10′ in declination could be conveniently and rapidly observed. The circle readings were taken at the beginning and end of each set of observations, and were found to remain remarkably constant. The optical power of the instrument is so great, that stars down to the tenth magnitude can be observed, and consequently, in the mode of observation just described, many more stars were taken than were required in order to carry out the plan laid down by the German Astronomical Society. Accordingly, the plan of observation has been lately modified, so as to make it conform more closely to the programme of the Society, and Mr. Simms has made a few alterations in the instrument which have rendered it more suitable for the class of observations required.

The bisection of a star with a single declination wire was found to interfere seriously with the right-ascension observations, so that in the case of very small stars it was found necessary to complete the right-ascension observations before the bisection was made. In order to remedy this, the single wire has been replaced by two parallel wires, 10″ apart ; and two similar pairs of wires have been added, each at the distance of about 5′ from the central pair, to give increased facility of bisection in particular cases.

The tangent screw handles have been made more accessible to the observers, one being under the control of the assistant who reads the microscopes, and enabling him to set the instrument with great rapidity within a range of more than half a degree ; the other is controlled by the right-ascension observer who makes the bisection.

Mr. Graham has adopted a method of determining the intervals

of the right-ascension wires which has been found to be very accurate and convenient. The eyepiece is turned through 90°, and each of the right-ascension wires, now become horizontal, is in turn directed to the horizontal wires of either collimator, and the corresponding readings of both circles are taken.

The values of the revolutions of the micrometer-screws have been found in a similar way with great accuracy.

Small buildings have been erected over the Collimators, which are now therefore virtually in the same room with the Transit Circle, and the consequent steadiness in the images of the collimator wires is very remarkable.

For clock corrections the catalogue of 529 stars issued by the German Astronomical Society has been used. About six of these stars are generally taken in the course of the night's work in addition to the stars near the pole which are observed for instrumental deviation. For instrumental errors, *Polaris* has been observed sixty-six times above the pole and seventy-six times below; and δ *Ursæ Minoris* eleven times above and ten below; 51 *Cephei* seven times above and two below; and λ *Ursæ Minoris* five times above and three below. *Neptune* has been observed eleven times near the opposition.

Observations for finding the errors of level and collimation, and for determining the zenith point, are made daily in observing weather. The error of collimation has been determined 189 times, the error of level 227 times, and the zenith point 236 times. All those errors have been calculated and applied to the observed transits of standard stars throughout the year. The clock corrections and rates are also calculated.

Mr. Simms has rendered the counterpoises much more sensitive by supporting the fulcrums of the levers on knife edges. He has also made some improvements in the driving-clock of the Northumberland Equatoreal, though its performance is still far from satisfactory.

Very little time could be given to extra-meridional observations, but some good observations were obtained of Encke's Comet. The meteorological observations have been made at the usual hours of nine A.M. and three P.M.

Dunsink (Dublin) Observatory.

During the past year Dr. Brünnow has completed the observations on the parallax of five stars, namely, *Groombridge* 1830, *Bradley* 3077, 85 *Pegasi*, 6 *Draconis*, and α *Lyræ*, the two latter having been compared with different stars from those used in the former series. These observations have all been computed and their results are now being printed. Two new series have been commenced on the parallax of the Planetary Nebula, H. IV. 37, and on 61 *Cygni*. The meridional observations have been interrupted for the greater part of the year, as the Transit

instrument was taken down, and the Circle admitted only of a very limited use, on account of extensive alterations in the observing-room, which were required for the mounting of a large Meridian-circle, which is shortly expected.

Royal Observatory, Edinburgh.

A meeting of the Board of Visitors of this Observatory was held in July, and a Report, then presented to them by the Astronomer, was afterwards printed and published in November. It contains twenty-six pages of letter-press with five plates, and sufficiently describes all details of work up to that date.

Since then, on January 17, the Astronomer writes that he is within a few pages of the end of Volume XIII. of the Edinburgh Observatory series. It is the largest volume yet issued from this establishment; it has occupied upwards of two years uninterruptedly in preparation, and contains all the more useful observations made during the interval from 1860 to 1869, with some additions to 1871.

Durham Observatory.

After holding the Directorship of the Durham Observatory for more than thirty years, the Rev. Professor Chevallier has resigned that trust during the course of the past year, to the deep regret of all interested in the progress of practical astronomy and the welfare of this establishment. No successor to Mr. Chevallier has yet been appointed.

The work performed during the past year has been chiefly the extra-meridional observation of minor planets, as in previous years, preferring those more recently discovered, which have been bright enough to come within the optical means of the Equatoreal. Some trustworthy observations of Encke's Comet have also been obtained. The reductions of these are all in an advanced state, and will be communicated shortly to the *Astronomische Nachrichten*. Two abstracts of results of Equatoreal work have been published in that journal during the past year, the first communication being of Cometary, the second of Planetary Observations. The spectrum of the Aurora Borealis has been examined on several occasions, notably on November 9; but, beyond the verification of the well-known green line, with only negative results. Some success attended an attempt to measure the diameter of the first optical ring of light round the image of the star *Polaris* by its transit over the meridional wires of the Transit Circle; but the observation, though easily and satisfactorily made, and though agreeing with a similar determination made two years ago, does not agree with the diameter which theory assigns for the object-glass employed.

The regular course of meteorological observations has been continued without intermission, forming the twenty-second year of the series, and an annual meteorological summary has been compiled as usual; but it remains only in manuscript.

Glasgow Observatory.

The operations at the Glasgow Observatory during the past year have not been distinguished by any deviation from the system pursued in former years. The superintendence of the electrical arrangements connected with the transmission of Greenwich mean time to the City and Port of Glasgow has recently been transferred from the Magnetic Telegraph Company to the authorities of her Majesty's Post Office, and is characterised by the same efficiency as heretofore. Prof. Grant hopes in the course of another year to bring to a close a series of star observations with the Transit Circle which for several years past have occupied the whole resources of the Observatory, and that henceforward he will be enabled to devote more attention to observations out of the meridian. A few observations of the Comets of Encke and Tempel have been obtained with the Ochtertyre equatoreal.

Liverpool Observatory.

Bidston, Birkenhead.

The work at this Observatory during the past year has been chiefly confined to the communication of time to the Port, the testing of nautical instruments, and to meteorological observations.

The firing of a gun at 1^h P.M. daily is more highly appreciated than any other method of communicating time that has been adopted at Liverpool; the flash of the gun is well seen from the river and docks, and the sound is well heard in the towns of Liverpool and Birkenhead.

During the past year between three and four hundred chronometers have been tested. There appears to be wanting for the Mercantile Marine some standard of authority to appeal to for those who are interested in the performance of chronometers, in order to judge if their own instruments are of average goodness as regards regularity of performance and thermal adjustment. It is hoped that the method of exhibiting the rates of these instruments now in use at the Liverpool Observatory may to some extent be found to supply this deficiency.

The certificates of test supplied to the owners of the instruments which are sent to this Observatory show the daily rates for five consecutive weeks.

The temperature is changed 15° at the end of each week throughout the year, and all the chronometers at the Observatory

are subjected to the definite temperatures of 55°, 70°, and 85° of Fahrenheit in succession.

In Mr. Hartnup's report to the Mersey Docks and Harbour Board for the year 1870, it will be seen that, for 381 chronometers tested in this way, the mean of all the greatest differences of daily rate between any two weeks is $2^{s}\cdot14$ and that $1^{s}\cdot61$, or about three-fourths, of this appears to be due to error in thermal adjustment.

In order to render the information thus obtained available for comparison the rotation number, showing the order in which the instrument was received at the Observatory, has been supplied with each certificate of test. At the end of each year an abstract of the rate of each chronometer with its rotation number is published so that by preserving this number the owner of any chronometer tested at the Observatory may, by means of the printed abstracts, compare its performance with that of any other instrument, or with the average of all tested during the year, and may immediately see whether the regularity of performance was better or worse than the average.

The Liverpool Observatory was not originally supplied with self-registering meteorological instruments, but their erection was subsequently urged upon the authorities of Liverpool by merchants and scientific gentlemen resident in the town and neighbourhood. Applications are frequently made for extracts from meteorological records months and even years subsequent to the date on which the various phenomena have been recorded, and a table of results for the year 1870, which is intended to supply the information generally applied for, has been published in the Report for that year.

The testing of nautical instruments, and the taking and reducing of meteorological observations, have so much occupied the time of Mr. Hartnup during the past two years, that with but one assistant he has been able to do but very little work with the equatoreal.

Stonyhurst Observatory.

The chief improvement since last year is the adaptation of a photographic apparatus to the Equatoreal, with the view of obtaining enlarged pictures of sun-spots. Images of various sizes were photographed during the summer months, and the scale finally adopted was that of $17\frac{1}{2}$ inches to the solar diameter. Mr. Pateson, the photographer of the Preston Town Council, most kindly aided in making the necessary arrangements. The end proposed is to procure a series of photographic records of the daily, or even more rapid, changes in any remarkable spot, or group of spots.

Connected with the magnetic department of this observatory a survey of Belgium was undertaken during the months of August and September. The magnetic declination, dip, and

horizontal force, were observed at about 20 stations, and these observations are at present in course of reduction.

Kew Observatory.

The photographic solar observations have proceeded during the last year with great regularity, under the superintendence of Mr. De La Rue, and have been so much favoured by the weather, that on 226 days 381 photograms have been taken, a result far exceeding that of any previous year. The reductions and investigations necessary for the intended determination of the Sun's elements have progressed vigorously, and are now completed up to the end of the year 1869, while two independent papers, one having reference to a distinct law in the form of the sun-spot curve, and published by the Royal Society ; the other, giving further evidence of the interplanetary relations of the Sun as shown by its activity, and handed in for publication,—have also been prepared during that time. The special summary for last year will be laid before the Royal Astronomical Society very shortly.

The past year is the last in the ten-yearly period during which the Photoheliograph at Kew has been at work, and within a very few days the continuous photographic record of the Sun's disk will in this country draw to a close. How great a loss this is for astronomical science, especially at the present time when the inquiries into the physical nature of the Sun form so prominent a part in the activity of astronomers, will be seen by the statement that during these ten years no less than 2778 solar photograms have been taken, preserving almost for all time the most faithful record of fleeting phenomena, still surrounded with profound mystery and great interest, and still promising the most surprising disclosures of the widest bearing. About twenty papers, embodying laborious investigations and discussions, have been communicated during that time to the Royal Society and the Royal Astronomical Society, by the observers engaged in the Kew solar researches, and have been published.

The completion of the reductions for the years 1870 and 1871, as well as the final discussion of the whole series, will be completed at Mr. De La Rue's expense, and will take about one year and a half. The paper containing this last instalment of the work will, it is confidently expected, be a conclusive proof in itself that solar-eye observations can no longer compete with photographic in the absolute reliability of the facts deduced. Concurrently with the discussion of the Sun-spots, the relative amount of faculæ will be measured in the Kew pictures, as there is reason to think that important conclusions may be drawn in regard of solar activity by a study of the faculæ. All the Kew pictures may not be available for this purpose, but in future, pictures can be taken in which the faculæ will be most carefully defined, by so regulating the exposure of the photograph that these entities may be rendered very

conspicuous. It is satisfactory that there is a prospect that a record of the Sun's activity will be continued by the Wilna Photoheliograph ; and that, after the lapse of a year or two, a new Photoheliograph, with all those improvements and perfections which advanced knowledge and past shortcomings have suggested, will be erected in this country by Mr. De La Rue. In the meantime the Royal Society have sanctioned the replacement of the secondary magnifier (an ordinary Huyghenian eye-piece) of the Kew instrument by a positive eye-piece achromatised for the chemical rays, as in the Wilna instrument.

Statement of the work done at the Kew Observatory with the Heliograph.

Year.	Number of Days of Observations.	Number of Pictures Obtained.	Remarks.
1862	163	227	Pictures taken at Cranford.
1863	125*	184	Instrument mounted at Kew. Pictures commenced in May.
1864	164	249	
1865	159	277	
1866	157	262	
1867	131	187	No observations made between Aug. 9 and Sept. 9 ; building under alteration.
1868	174	285	
1869	195	324	
1870	220	381	
1871	226	381	
1872	10	21	January only.
Total	1724†	2778	

Mr. Huggins' Observatory.

During the past year the large Grubb Equatoreal, and the new spectroscopes constructed for use with it, have been got into adjustment, and some work has been done, though the long continuance of bad weather during the autumn left but few favourable nights for observation.

Measures have been taken of the remarkable bands of absorption in the spectra of *Uranus* and *Neptune*. The spectra of Comet I. 1871 and Encke's Comet were found to be similar to those of former comets examined at Tulse Hill. An account of these observations and drawings of the appearance of Encke's Comet will be found in the *Proceedings of the Royal Society*.

* Spots were unusually scarce this year.

† The number of good observation days seem to be greatest at the times of maximum spots.

Some observations on the spectra of nebulæ, and on the motion of stars in the line of sight, are at present not completed ; but it is expected that the velocity of *Sirius* from the Earth will be found to be smaller than the estimate which Mr. Huggins obtained with the less powerful instruments then at his command.

Some quite recent observations of the change of refrangibility of the Fraunhofer lines at the opposite limbs of the Sun appear to show a motion in the atmosphere producing the Fraunhofer lines greater than that which is indicated for the photosphere by the movements of the spots.

Mr. Bishop's Observatory.

The principal work of the past year has been the continuation of the charts or stars within three degrees north and south of the ecliptic, to the eleventh magnitude inclusive. It has been found necessary to introduce a considerable increase in the measure of the square degree for those parts of the ecliptic where it is traversed by the Galaxy, in order to show distinctly the great number of small stars which the charts include. Much additional zone-work has also been required, but the whole is now in a sufficiently advanced state to allow of the re-issue of the charts commencing in the present month, with the hope of maintaining a regular publication during the year. In this district, the nights available for small-star-work have been by no means up to the average. Encke's comet has been satisfactorily observed for position on sixteen nights up to December 6. The small comet, discovered by M. Tempel, on November 3, was observed on four nights. It is Mr. Bishop's intention to combine calculation, with observation, in the proceedings of his Observatory. During the past year a full discussion of the observations of the Great Comet of 1861 has been completed by Mr. W. E. Plummer : the number of observations approaches one thousand ; all sensible planetary perturbations have been taken into account, and the final orbit depends upon normals on which the whole of the observations about the respective dates have been brought to bear. The main result of the investigation is to indicate that the comet was moving in an ellipse with a period of 402 years ; the details are now in course of arrangement for publication. Upon the suggestion of Mr. Hind, Mr. Bishop has undertaken the calculation of the effect of planetary attraction upon Encke's comet during the next revolution, and hence the preparation of an ephemeris for the reappearance in the spring of 1875. Very little has been done in England in this department of astronomy, and although it has been announced by the German Astronomical Society that an experienced computer proposes to occupy himself with a similar investigation, it appears to be intended to apply a new method, and it will be at least satisfactory in this case to possess a duplicate calculation. Mr. Plummer is now engaged in the preliminary correction of the predicted elements from the observations of 1871, after which he will apply

with every accuracy the method of computation indicated by the Astronomer Royal, with certain modifications to suit this particular case. An ephemeris of Tuttle's comet, of short period, for the Southern hemisphere, was issued from this observatory, by the aid of which Mr. Stone had been able to observe it at the Cape of Good Hope in the middle of December. The periodical comet of De Vico, which has not been detected since its appearance in 1844, has been sought for on the assumption that a perihelion passage might take place in the autumn of 1871. It now appears probable that this did not occur between August and November.

Royal Observatory, Cape of Good Hope.

The chief attention of the staff has been directed to the reduction and passing through the press of the observations made with the Transit-Circle, in order to bring forward a catalogue of stars from observations made since the erection of that instrument. The Transit-Circle was brought systematically into use in 1856. The observations made in that year have been reduced, printed, and distributed. The observations made in 1857 have been printed, Those in 1858 have been partially printed. The reductions of the observations made in 1859 are in a forward state. The meteorological observations from 1841 to 1870 have been collected, discussed, and the results printed and distributed. The miscellaneous magnetical observations, not hitherto printed, have been collected, reduced when necessary, the means taken, and the results prepared for press. It is intended to append these miscellaneous observations to the volume containing the results for 1857 and 1858, which it is hoped may soon be ready for distribution.

The work of the Observatory has been much impeded since August by the illness, at one time, of no less than three of the staff, and the lamented death, on September 18, of Mr. Sinfield, an assistant of considerable experience and much promise. Much time has been devoted to the examination of the form of the pivots and the division-errors of the Transit-Circle. The observing with the Transit-Circle has been chiefly directed to observations of the zenith distance of circumpolar stars, wide and close, both above and below pole, to afford material for a separation of any existing errors in the refractions adopted, and the co-latitude of the observatory. Observations of *α Centauri*, *β Centauri*, and *α Eridani*, have been made to test the truth of the reference of a large systematic annual change in the zenith distances of *α Centauri*, observed at this observatory, to annual parallax.

A complete reobservation of all stars down to the seventh magnitude within 5° of the South Pole has also been made. Each star has been observed at least three times.

The Equatoreal has been employed upon observations of Winnecke's Comet I. 1871, Tuttle's comet, and a reobservation of many of Herschel's double stars. A few attempts have been

made to use the spectroscope with it, but without much success. The mounting is too weak and the driving-clock too defective for any employment of the Equatoreal upon such work with advantage. The aperture of the object-glass, seven inches, is small for such work upon faint objects.

The November meteors were carefully looked for, but very few were seen.

It is intended this year to observe the principal stars within the ecliptic limits for absolute right ascension—a point which has not previously received attention here. The changes of temperature between day and night are very considerable, and it has been thought necessary to protect the chief sidereal clock as far as possible against exposure to these changes. A change has, for this purpose, been prepared in the interior of the building where the changes of temperature from day to night are confined within a degree. The clock will stand upon a pier raised free from the walls and floors directly from the rocks below the building.

It is intended to repeat during the winter season the observation of the stars within 5° of the South Pole. Such observations are thought likely to be of value both for the determination of azimuthal errors in the Southern hemisphere, and also at some future period for an accurate determination of the constants connected with the motion of the polar axis by reference of its position to the mean of the group of stars rather than to one or two selected stars.

Sydney Observatory.

Mr. Russell, who succeeded Mr. Smalley in the charge of this Observatory, read a report on the state and progress of the Observatory during the year 1870, at the Annual Visitation held on September 7, 1871. A few extracts from the Report are here given :—

"From the commencement of the year up to the time of his lamented death on the 12th of July, 1870, the late Astronomer had charge of the base-line operations at Lake George, in addition to the Observatory, and during that time all that his failing health allowed him to do was devoted to the base-line. Greater part of the Computer's time was also given to the examination of the instruments, measuring-bars, and other things connected with the same work. Little, therefore, could be done in the Observatory except the regular observations with the transit-instrument, the meteorological work and its regular reduction and publication, together with the examination and preparation of thirty sets of meteorological instruments for the new stations.

"The transit-instrument was in constant use, but not in good order; the dust, which got to the bearings in spite of close-fitting caps, cut into the soft pivots, and then they were made rough into the agate planes and removed the polish, so that the wear was

very considerable (this has since been remedied and the instrument put in order). . . . In spite of every precaution most unsatisfactory jumps occur in the corrections of the transit, which can only be attributed to the quarrying, and especially the blasting, operations carried on near the Observatory. One person is removing stone from his own land, and has several times shaken the Observatory in such a way that no instruments could be expected to be accurate.

"I would strongly urge the advisability of getting a new transit-instrument, which shall be equal to the exact requirements of modern astronomy. With an instrument at the Cape of Good Hope equal to the Greenwich transit, and one almost equal at Melbourne, it seems a waste of energy to work with an instrument that was made more than thirty years since, and which never was a good one, even when new, either in plan or construction."

During the year 1870, 952 transits were observed, in addition to the usual observations for the instrumental adjustments, and 270 measures of the distance and angular position of double stars. Among the subjects of observation carried on in 1871, special attention was given to meridional observations of the Moon and Moon-culminating stars for the determination of the longitude, and to the measurement of distance and angle of position of as many circumpolar double stars as possible, and to the observation of the spectrum of a few of them.

Notes on some Points connected with the Progress of Astronomy during the Past Year.

The progress of Astronomy has been satisfactory during the last twelve months, as may be gathered from the various important subjects briefly alluded to in the following notes. The principal observatories have been steadily recording the results of their arduous and useful labours, storing up data for the future benefit of our science; while other observers, with less routine duties, have found time and zeal to discover several minor planets and comets, in addition to the usual amount of miscellaneous work. But perhaps the most important Astronomical observations during the year, and to which most attention has been given, were those of the Total Solar Eclipse of December 11 (Dec. 12, Civil reckoning), visible in Southern India, Ceylon, and Northern Australia. The generally successful results obtained in India and Ceylon, both with the spectroscope and by photography, will probably explain definitively many undecided points relating to the constitution of the Sun's chromosphere and corona.

Total Solar Eclipse of Dec. 11 (*Dec.* 12, *Civil Reckoning*), 1871.

In the last Annual Report will be found a summary of the observations of the Total Eclipse of December 1870. The bad

weather which prevailed at many of the observing stations rendered the results of this eclipse far less complete than was expected from the careful preparations which had been made. The new information, though a considerable and important gain, was not complete enough to warrant a definitive opinion on the several points connected with solar phenomena on which we were seeking to increase our knowledge. The extent and nature of the coronal light and rays surrounding the eclipsed Sun were left so far not conclusively settled as to allow great differences of opinion still to exist.

It was therefore most fortunate for science that another Total Eclipse visible in our own possessions,—in India and in the north of Australia,—would take place during the past year.

We rejoice to learn that the weather was favourable at nearly all the observing stations in India, and that very satisfactory observations and good photographs have been obtained. It is with great regret that we receive a telegram to say that bad weather prevailed in Australia. The reports which have reached the Council are as yet too incomplete for it to be desirable to attempt any discussion of the bearing of the observations on the great questions of the true nature and extent of the coronal light and rays. Such a discussion can be only properly made when the reports of all the observers have been received, and when the valuable photographs of the Sun's surroundings obtained at the different stations have been carefully examined and compared with each other. We therefore confine ourselves to giving some of the principal results obtained at each station as far as they have reached us, in the observers' own words.

Colonel Tennant, who through the liberality of Lord Mayo had been able to organise a strong observing party, including Capt. Herschel and Mr. Hennessy, selected the old meteorological station of Dodabetta, on the highest peak of the Neilgherries, 8650 feet above the sea. He telegraphed his principal results in the following words, "Thin mist, spectroscope satisfactory. Reversion of lines entirely confirmed. Six good photographs." In a letter addressed to one of the Secretaries, Col. Tennant writes:—

"I had my attention specially directed to the chromosphere and prominences at the true bottom of the Moon's limb. They first appeared *white*, and then changed through pink to red. I am quite confident that I saw no blue or green tinge. You will remember my suspicion that I do not readily see blue when faint, but I am sure the tint was not strong. My waiting in the Moon's centre gave me an opportunity of looking about me, and I saw the two rifts I have spoken of. To me they did not reach the Moon's edge, but were separated by some minutes of bright corona. The corona's outer layers were undoubtedly radiated, but not coloured. There were alternate gradations of light; that is, light and comparative darkness, but certainly no colour. The rays were lost as they neared the Moon. The rift at the

true vertex of the Sun I am sure did not change, nor I believe did any other. Colonel Saxton had made for my object-glass a loose cap of pasteboard, with a two and a half inch aperture to be used during the Sun's presence; this was to have been knocked off just before totality. I forgot this, but I doubt if I should have improved matters; I used the power 35.

"I had asked Captain Morant, R.E. (to whom I am indebted for a very great amount of assistance), to take a very beautiful reconnoitring telescope by Dallmeyer, which was mounted on a stand. Of 14 inches focus, it has a power of 15 and an aperture of 1·75 inches. He (Captain Morant) made two sketches of the corona, which generally confirm, as does his description, all I have described. He expressed himself positive as to the absence of colour and the permanence of rifts, &c., in certain positions (not mine), and only differed in thinking that the shades were of a sepia tinge (brownish) and that the rifts did extend to the Moon."

The Madras astronomer, Mr. Pogson, observed at Avenashy. He telegraphed to the Astronomer Royal, "Weather fine, telescopic and camera photographs successful, ditto polarisation; good sketches; many bright lines in spectrum."

In a letter to the Astronomer Royal, Mr. Pogson writes:— "As my telegram informed you, we were upon the whole successful—more so than I ventured to anticipate—much less so than I could have wished. With the spectroscope I saw five lines; one bright and fine, right across the field, evidently my old Masulipatam friend, which the Americans call 1474. This was, I believe, the only bright corona line—the *only one I saw*—the other four were only part-way across, two in the blue and two near together in the deep red, *i. e.* where such colours are assuredly seen, and certainly prominence lines. With the Browning reflector my son and Col. Ritherdon together got three photographs, all available, but two, as I consider, *very* good. These show the corona some five or seven minutes in extent, but are all over-exposed. Thirty seconds each was allowed, as suggested by Mr. De La Rue; but I think ten would have been better, and we could have had more views. With a camera four views were taken—three very good—by Mr. Cruths, a professional. The polarisation was, I believe, very good and satisfactory; measured near the Sun's south (right hand) limb, and some distance off, and decidedly stronger further off the Sun than close to it. The sketches were very good, and will, I think, be valuable and reliable, and the ordinary contacts and some distances and angles of position of the cusps were also carefully secured."

Dr. Janssen has addressed the following letter to the President:—

J'aurai l'honneur d'adresser à la Société Royale Astronomique un mémoire détaillé de mes observations de l'Eclipse, mais je profite du départ de ce courrier pour vous informer des principaux résultats obtenus.

Sans entrer dans une discussion qui fera partie de ma relation, je dirai d'abord que la magnifique couronne observée à Sholoor s'est montrée sous un aspect tel qu'il me paraîtrait impossible d'admettre ici une cause des phénomènes, ou de diffraction, ou de réflexion sur le globe lunaire, ou encore de simple illumination de l'atmosphère terrestre.

Mais les raisons qui militent en faveur d'une cause objective et circumsolaire prennent une force invincible quand on interroge les élémens lumineux du phénomène.

En effet, le spectre de la couronne s'est montré dans mon télescope, non pas continu comme on l'avait trouvé jusqu'ici, mais remarquablement complexe. J'y ai constaté :

Les raies brillantes, quoique bien plus faibles, du gaz hydrogène qui forme le principal élément des protubérances et de la Chromosphère ;

La raie brillante verte qui a déjà été signalée en 1869 et 1870, et quelques autres plus faibles ;

Des raies obscures du spectre solaire ordinaire, notamment celle du sodium (D.) Ces raies sont bien plus difficiles à apercevoir.

Ces faits prouvent l'existence de matière dans le voisinage du Soleil, matière qui se manifeste dans les éclipses totales par des phénomènes d'émission, d'absorption, et de polarisation.

Mais la discussion des faits nous conduit plus loin encore.

Outre la matière cosmique, indépendante du Soleil, qui doit exister dans le voisinage de cet astre, les observations démontrent l'existence d'une atmosphère étendue, excessivement rare, à base d'hydrogène, s'étendant beaucoup au de-là de la Chromosphère et des protubérances, et s'alimentant de la matière même de celles-ci, matière lancée avec tant de violence à travers la photosphère, ainsi que nous le constatons tous les jours.

La rareté de cette atmosphère, à une certaine distance de la Chromosphère, doit être excessive ; son existence n'est donc point en désaccord avec les observations de quelques passages de comètes près du Soleil.

Neelgherry, Sholoor, 19 Décembre, 1871.

From the English party sent out at the expense of the Government at the instance of the British Association, the following reports have reached us.

Mr. Lockyer, who observed at Bekul, speaking of the corona says, "Its rays arranged almost symmetrically, three above and three below two dark spaces or rifts at the extremities of a horizontal diameter. The rays were built up of innumerable bright lines of different lengths, with more or less dark spaces between ; near the Sun this structure was lost in the brightness of the central ring. I next tried the spectrum of a streamer above the point at which the Sun had disappeared. I got a vivid hydrogen spectrum with 1474 (I assume the point of this line from observation) slightly extended beyond it, but very faint throughout its

length compared with what I had anticipated and thickening downwards like F. I was, however, astonished at the vividness of the C line and of the continuous spectrum, for there was no prominence on the slit; the spectrum was undoubtedly the spectrum of glowing gas. In the Savart I saw lines vertical over everything, corona, prominences, dark Moon, and unoccupied sky." With a simple train of prisms Mr. Lockyer saw "four exquisite rings with projections where the prominences were. In brightness C came first, then F, then G, and last of all 1474. The rings were nearly all the same thickness, certainly not more than 2′ high, and they were all enveloped in a line of impure continuous spectrum." "The structure of the corona was simply exquisite and strongly developed, I at once exclaimed, 'Like *Orion*.' Thousands of interlacing filaments varying in intensity were visible. I saw an extension of the prominence structure in cooler material. This died out somewhat suddenly some 5′ or 6′ from the Sun, and then there was nothing. The great fact was this, that close to the Sun and even for 5′ or 6′ away from the Sun, there was nothing like a ray or any trace of radial structure." At this station five good photographs were obtained.

Commander Maclear observing at the same station says, "As totality came on the light decreased and the lines increased exceedingly, rapidly in number and brightness, until it seemed as if every line in the solar spectrum was reversed; then they vanished not instantly, but so quickly, that I could not make out the order of their going, except that the Hyd. D *b*, and some others between D and *b*, remained last. Then they vanished and all was darkness. I then unclamped and swept out right and left, but saw nothing; then went to the direct vision, but saw nothing; placed the telescope on the Moon's limb by the eye-piece, then put in the spectroscope, but the light was not sufficient to show any spectrum; pointed the telescope carefully first on the dark Moon, and then on a bright part of the corona, but no spectrum. I then looked at the corona with the naked eye, saw a bright glory round the Moon, stellar form, six-pointed something like the nimbus painted round a saint's head, extending to a diameter and a half. Looked through the finder and saw the same form, but very much reduced in size and brilliancy, then examined with the 6-inch and eye-piece and saw nothing but a bright glow round the Moon, not much more than the height of the big prominence plainly visible in the south-east quarter."

Prof. Respighi observed at Poodocottah. He writes, "Towards the end of 1868 a small flint-glass prism was made for me by Signor Merz of Monaco to be fitted to the object-glass of the equatoreal of the observatory at Campodoglio. This apparatus, in consequence of the dispersion of the prism and the goodness of the prism and object-glass, was found to be admirably adapted for observing the eclipse in the manner just described (that is, without a slit, so that the several chromatic images of the corona would be simultaneously seen in the same field of view).

"The dispersion of the prism from lines C to H is about 32′; the free aperture of the object-glass is 4⅓ French inches; the field of the telescope about 1°, with a magnifying power of 40." "At the very instant of totality, the chromosphere at the edge which was the last to be eclipsed—surmounted for a space of about 50° by two groups of prominences, one on the right, the other on the left, of the point of contact—were reproduced in the four spectral lines C, D^3, F, G. My attention was mainly directed to the comparison of the forms of the prominences on the four spectral lines, and I was able to determine that the fundamental form, the skeleton or trunk, and principal branches, were faithfully reproduced or indicated in the images, their extent being, however, greatest in the red, and diminishing successively in the other colours down to the line G, on which the trunk alone was reproduced. In none of the prominences thus compared was I able to distinguish in the yellow image D^3 parts or branches not contained in the red image C. Meanwhile the coloured zones of the corona became continually more marked, one in the red corresponding with the line C, another in the green, probably coinciding with line 1474 K, and a third in the blue, perhaps coinciding with F.

"The green zone surrounding the disk of the Moon was the brightest, the most uniform, and the best defined. The red zone was always distinct and well defined, while the blue zone was faint and indistinct. The green zone was well defined at the summit, though less bright than at the base; its form was sensibly circular and its height about 6′ or 7′. The red zone exhibited the same form and approximately the same height as the green, but its light was weaker and less uniform. These coloured zones shone out upon a faintly illuminated ground without any marked trace of colour. If the corona contained rays of any other kind, their intensity must have been so feeble that they were merged in the general illumination of the field. . . . . The spaces between some of the jets (prominences) were perfectly dark, so that the red zone of the corona appeared to be entirely wanting there. Perhaps, however, this was only an effect of contrast due to the extraordinary brightness of the neighbouring jets.

"The green and red zones were well developed at the western as at the eastern limb, while the blue remained faint and ill-defined. Soon after the appearance of the chromosphere at the western edge, there was suddenly projected on the spectrum of the Sun's limb, which then appeared beyond that of the Moon, a stratum of bright lines, separated by dark spaces, but I could not determine whether they were due to a general or partial reversal of the spectral solar lines, or to a simple discontinuity in the spectrum."

Capt. Tupman, who was stationed at Jaffna, Ceylon, observed the different phenomena as follows:—

"1. The corona extended 40′–50′ from the limb of the Moon.

2. An oblique ray 28′ to 30′ long, two-thirds up a curve ray, like the crook of a boat-hook 12′ long.
3. A sharply-defined rift, with sides forming a right-angle.
4. A narrow rift, very dark, approaching within 2′ or 3′ of the prominences, and still distinct 45′ from them.
5. Another rift opposite to 3.
6. Strong radial polarization with a Savart, extending to 50′ from the Sun. The corona polarization was so strong as entirely to overcome the air polarization. The polarization remained visible as radial upon the corona until 25^s, or perhaps 35^s, after totality.
7. 1474 K was much the brightest line in the integrating spectroscope. Capt. Fyers saw the four lines C, D^3, 1474 K, and F; also Young's bright reversed lines."

Spectrum Analysis.

Dr. Zöllner has contrived a more simple form of reversion Spectroscope, by which the principle of doubling the change produced in the refrangibility of a line can be applied to any spectroscope. The object-glass of the telescope of the spectroscope is divided, and in front of one half a right-angled prism is placed so that the spectrum seen through it by reflection is reversed. With this instrument Zöllner has succeeded, with the assistance of Dr. Vögel, Director of the observatory at Bothkamp, in detecting the change of refrangibility due to the Sun's rotation. The estimations of the amount of the change subsequently made by Dr. Vögel are in excess of the period of rotation obtained from observations of solar spots, the equatorial velocity ranging from 0·35 to 0·42 mile in a second, while the received value is 0·27 mile. The instrument awaits some minor improvements before reliable quantitative results can be obtained.

Professor Young was fortunate in observing an ejection of matter by an apparent explosion in the Sun, which took place on September 7. At noon on that day he observed an enormous protuberance of hydrogen cloud on the eastern limb of the Sun. It had remained with little change since noon of the preceding day. It was made up mostly of filaments nearly horizontal, with its lower surface at a height of some 15,000 miles; but was connected with the layer of red hydrogen by three or four vertical columns, brighter and more active than the rest. Returning to the telescope half-an-hour later, Professor Young found, in place of the quiet cloud, a mass of detached vertical fusiform filaments rapidly ascending. Some of them had already reached a height of 100,000 miles, and they continued to rise with a motion almost perceptible to the eye until, in ten minutes, the uppermost were more than 200,000 miles above the solar surface, the velocity of ascent was therefore 166 miles per second. We must refer our readers for the details of this important ob-

servation to Professor Young's paper. A notice of some of the conclusions suggested by this observation, as to physics of the Sun, which have been investigated by our fellow Mr. Proctor, will be found in another part of this Report.

Father Secchi has suggested a modification of the usual spectroscopic method of viewing the prominences which may be of service in some observations. He places a prism before the object-glass of the astronomical telescope, or else a direct-vision spectroscope within the telescope, some 6 or 8 inches in front of the slit of the ordinary spectroscope. By this arrangement the Sun's disk can be viewed in the spectroscope; and if the slit be placed on a prominence near the solar limb, and the spectroscope arranged for the position of C, then, together with the solar limb, will be seen a bright line of the prominence at a distance from the Sun's limb, depending on the position of the slit relatively to the solar image, but not exceeding the height of the prominence under observation.

We are also indebted to the ingenuity of Father Secchi for a new method of measuring the height of the prominences seen in the spectroscope, the details of which will be found in the *Comptes Rendus* for December 4, 1871.

Professor Young has done a very valuable service to spectroscopic observers of the Sun by publishing a catalogue of all the lines which have been observed in the solar prominences and corona. These lines, 103 in number, are arranged in the order of their wave-lengths, and the corresponding numbers of Kirchhoff's maps are given. Other columns of the catalogue contain the relative brightness, and frequency of the lines, and the names of the chemical elements to which they belong. No fewer than twenty of the lines are due to the vapour of titanium. Besides the well-known coronal line 1474 of Kirchhoff's scale, two other fainter lines, one less refrangible than C, and the other between F and G, appear, according to Professor Young, to be persistently present in the corona or chromosphere, and probably to be due to the matter of which it consists, and not, as is the case with most of the other lines, to the occasional elevation of matter to heights where it does not properly belong.

The solar prominences have been assiduously observed by the spectroscopic method during the past year by Professor Young, Father Secchi, Professors Respighi and Tacchini. These observations seem to establish the convenient arrangement of these objects into cloud-like and eruption forms; through these observations we are gradually gaining valuable information on many points which are intimately connected with the conditions under which the solar energies are manifested, such as the relation which the prominences sustain to the faculæ and to the spots, the solar zones in which they most frequently present themselves, the mode of their formation, and the density of the solar atmosphere or corona into which they are injected.

Mr. Huggins has succeeded in observing the spectrum of the

planet *Uranus*. He finds the spectrum of *Uranus* continuous, no part being wanting so far as the feebleness of its light permits it to be traced, which is from about C to about G. The absorption taking place at *Uranus* shows itself in six strong lines. One of these, the most refrangible, appeared to be coincident with the line F of hydrogen, with which line (in the spectrum obtained from rarefied hydrogen, rendered luminous by the induction spark) it was directly compared. The positions of this and four other lines were also obtained by micrometrical measures. There is no strong line in the spectrum of *Uranus* in the positions of the strongest lines of air, namely, the double line of nitrogen. There are no absorption bands in the position of the line of sodium, or in that of any line of carbonic acid gas.

Mr. Huggins has also examined spectroscopically the light of Comet I, 1871, discovered by Dr. Winnecke, and of Encke's Comet. Both comets gave a spectrum of three bright bands, agreeing in position with the principal bands of the spectrum of carbon, and similar to the spectra of former comets examined by Mr. Huggins.

Discovery of Minor Planets.

The list of Minor Planets has been increased by five since the last Annual Report. By this addition the total number at the present time is *one hundred and seventeen*. The new members of the group are:—

1. *Amalthæa* (113), discovered, on 1871, March 12, by Dr. R. Luther, at Bilk, near Dusseldorf.
2. *Cassandra* (114), discovered, on July 24, by Dr. C. H. F. Peters, at Hamilton College, Clinton, New York.
3. (115), discovered, on August 6, by Mr. Watson, at Ann Arbor, Michigan.
4. *Sirona* (116), discovered on September 8, by Dr. Peters, at Hamilton College, Clinton. This Planet was independently discovered by Dr. R. Luther on September 14.
5. *Lomia* (117), discovered, on September 12, by M. Borelly, at Marseilles.

It is proper to remark here that several of the minor planets pass through their opposition without being observed on the meridian, for want of an ephemeris. This has been more than usually the case during the past year. The number of planets is now so large that the calculations of ephemerides for all that come into opposition during the year is really a work of considerable labour, and is one which is annually increasing. Hitherto the *Berliner Jahrbuch* has voluntarily undertaken these calculations with great advantage to all who are interested in the observation of the minor planets. A list of the computers who assisted in this work was given in the Annual Report two years ago. The *Berliner Jahrbuch* for 1873 contained the daily tabular places near opposition of fifty-eight minor planets for 1871; but some of the oldest and largest members of the

group were not included among them, and have therefore escaped observation with the meridional instruments of Greenwich and Paris, and probably of other observatories also.

Comets.

Six comets have been visible during the past year. Two of them, Encke's and Tuttle's, were expected to return to perihelion in 1871, but the remaining four appear never to have been observed before. They are here given, named in the order of their discovery or first observation:—

1. Comet I. 1871, discovered, on April 7, by Dr. Winnecke, at Carlsruhe.
2. Comet II. 1871, discovered, on June 14, by M. Tempel, at Milan.
3. Comet III. 1871 (Periodic Comet of Encke), first observed, on October 4, by Dr. Dunér, at Lund. This Comet was first seen in England on October 8, by Mr. Hind.
4. Comet IV. 1871 (Periodic Comet of Tuttle), first observed, on October 12, by M. Borelly, at Marseilles. Dr. Winnecke detected it on October 14.
5. Comet V. 1871, discovered, on November 3, by M. Tempel, at Milan.
6. Comet VI. 1871, discovered, on December 29, by M. Tempel, at Milan.

Encke's comet has been examined by several observers provided with large telescopes. Its discovery was much facilitated by the aid of a daily ephemeris calculated by M. von Glasenapp, of Pulkowa, extending from August 18 to December 18, 1871. The comparison of the first observations with this ephemeris showed that it had at that time an error of 39^s in right ascension, and about $8'$ in declination. A corrected ephemeris was afterwards issued by Mr. Hind. When first seen the comet presented the appearance of a nearly round faint nebulosity, without apparent condensation in any part. By the beginning of November the remarkable fan-like form which has distinguished this appearance of the comet was well marked. A minute stellar nucleus was situated at the eastern point of the fan. On the other side, towards the Sun, which the comet was approaching, the cometary matter was spread out until it was lost to view from faintness. During November the cometary matter on the side from the Sun seemed arrested a short distance behind the apex of the fan where its boundary was seen as a right line perpendicular to the longer axis of the fan-like form. Early in December a faint beam was seen to be projected from this side forming a true tail.

The periodical comet of Tuttle has returned to perihelion, as was expected; but it does not appear to have been observed in England. It has, however, been observed at Marseilles, Carlsruhe, Paris, the Cape, and at a few other places. The positions of Comets I. 1871, II. 1871, and V. 1871, have been well observed. The details of the observations and the elements of each comet are inserted in the *Astronomische Nachrichten*. Elements or ephemerides by Mr. Hind of most of the comets of the year will be found in the *Monthly Notices*.

Two of the prizes offered by the Imperial Academy of Sciences at Vienna for the discovery of telescopic comets have been awarded to Dr. Winnecke for his two new comets discovered in 1870, and one to M. Coggia for the discovery of Comet II. 1870.

Variations of Gravity in Western Russia.

As a necessary supplement to that great geodetical undertaking, the measurement of an arc of the meridian between the Danube and the Arctic Ocean, of which the late Professor Struve was the directing mind, an extensive series of pendulum observations for the determination of the variations of gravity extending throughout the length of that arc, has lately been made under the auspices of the Academy of Sciences of St. Petersburg. The work was intrusted to M. Sawitsch, assisted in 1865 by M. Lenz, and in 1866 and 1868 by M. Smyslof. M. Sawitsch has drawn up a full abstract of the results, which he has forwarded to the Society through the Astronomer Royal. This abstract will be published in the *Memoirs*.

The paper contains the details of the method employed in the observations, and also the resulting values of the length of the seconds pendulum at the twelve different stations, situated on the arc from Tornea in latitude 65° 51′ N., to Ismail in latitude 45° 20′ N, thus ranging over a meridional arc of more than twenty degrees. Two reversible pendulums, constructed with the greatest care by Repsold, were used in the observations. The observed results appear to be very accordant when compared with the corresponding values calculated from formulæ explained by M. Sawitsch in his paper, the sum of the positive residual errors being +0·0440 Paris lines, while the sum of the negative residuals is −0·0423 Paris lines. The greatest individual error between the observed and calculated lengths of the pendulum is at Tornea, where it amounts to 0·02 Paris lines. M. Sawitsch remarks that these individual errors depend probably partly upon errors of observation and partly upon anomalies in the intensities of terrestrial gravity.

Catalogue of Comets observed in China.

The volume of *Observations of Comets from* B.C. 611 *to* A.D. 1640, *extracted from the Chinese Annals*, translated from the Chinese by Mr. Williams, and lately published, is a very important contribution towards the ancient history of Astronomy, and one which must be very useful in cometary investigations. It is only as a labour of love that such a work could have been produced, and that such has been the case in the present instance has been very evident to those who have been officially connected with our respected Assistant-Secretary during the preparation of the manuscript for the press. Mr. Williams' attention was first directed to the examination of the old Chinese annals for records of comets in consequence of an application made to him by Mr.

Hind, who had discovered some discrepancy in the path of a comet under discussion by him, contained in M. Biot's Catalogue of Comets observed in China. This led to a systematic examination of Biot's catalogue, which was found to be far more incomplete than was expected, about 150 observations of comets recorded in the undermentioned works having been omitted by him. The whole of these will be found in this work.

In addition to a detailed Catalogue of the whole of the observations of Comets contained in the Chinese works, known respectively as the Encyclopædia of Ma Twan Lin and the She Ke, Mr. Williams has given a complete set of chronological tables showing the succession of the dynasties and of the emperors from the earliest period to the present time, and other tables to be employed with these for the reduction of Chinese time to European reckoning. The mode of using these tables is fully explained in the introductory remarks, which also contain much information of interest respecting Chinese Astronomy. He also has added a Chinese celestial atlas and reduced copies of the figures in Flamsteed's Atlas, with the principal Chinese asterisms laid down upon the corresponding Stars.

Mr. Williams' complete work in manuscript, containing in every instance the original text in the Chinese characters, has been presented by him to the Society, as mentioned in a former Report, and is therefore available to any Astronomer who may wish to compare the translation with the original Chinese.

Magnitudes of the Stars in the Southern Hemisphere.

The Council have been glad to hear that our Associate, Dr. Gould, has entered upon his labours at Cordoba, Argentine Republic, with every prospect of success. From a communication received from Dr. Gould, dated December 8, we learn that the formal inauguration of the Observatory took place in the autumn, having been delayed by many unexpected obstacles. This interruption to the commencement of the systematic observation of the zones of stars, which was the primary object of the foundation of the observatory, cannot be considered a loss to science, for Dr. Gould and his assistants have not been idle during the time occupied in the construction of the buildings. Following the example of Argelander, who has given us in his *Uranometria Nova* a systematic comparison of the magnitudes of the principal stars in the northern hemisphere, he has undertaken a detailed and laborious series of observations with the naked eye, with the object of forming a catalogue of the magnitudes of all the stars thus visible from 10° north of the equator to the south pole, from which a system of maps could afterwards be constructed representing the aspect of the heavens in those latitudes. On December 8, this important work was far advanced towards completion, and Dr. Gould expects it will be concluded by the time the instruments are ready for regular observation. The number of stars of which the magnitudes are recorded is over 7000, the lowest inserted

being designated 6·6 mag. There can be no doubt that this work of Dr. Gould will be accepted by Astronomers as of the same standard authority for the magnitudes of the stars of the Southern hemisphere, as that of Argelander is admitted to be for those of the Northern.

M. Delaunay's Lunar Tables.

When the Society had the pleasure of presenting its Medal to our distinguished Associate, M. Delaunay, Professor Adams remarked in his address that "the Council have decided that we ought not to await the appearance of M. Delaunay's supplementary researches before we mark emphatically our sense of the value of his labours," adding in a further remark, "I understand, also, that M. Delaunay is engaged in the construction of new Lunar Tables founded upon his theory." The Council are gratified to hear from M. Delaunay that the construction of the new Lunar Tables is now being pushed forward as rapidly as possible. The preparation of the work would have been in a far more advanced state if it had not been for the misfortunes through which the Paris Observatory, in common with other public establishments in that city, had to pass during the siege and the terrible reign of the Commune. M. Delaunay, however, trusts that nothing will now delay the publication of the Tables in a reasonable time from this date.

By the completion of this practical portion of his great work on the Theory of the Moon, M. Delaunay's lengthened theoretical researches will become available for a systematic comparison with observation. That they will stand this test has been fully and ably explained by Professor Adams, in his address on the presentation of the Medal two years ago. The following is the state of the computations at the present time, as reported by M. Delaunay :—"La construction des nouvelles Tables de la Lune est poussée avec toute l'activité possible. Les Tables de la longitude sont complètement terminées, et l'impression en est commencée. Les calculs pour les Tables de la latitude sont en partie effectués (moitié environ) : Les Tables de la parallaxe ne sont pas commencées."

The Greenwich Water-Telescope.

In the last Annual Report allusion was made to this instrument, erected at the Royal Observatory, Greenwich, and destined to the experimental solution of a problem important both in astronomy and physical optics; namely,—Whether any effect is produced on the constant of aberration by the passage of the rays through a refracting medium.

With the bearing of this question on the constitution of the luminiferous ether, astronomers are scarcely concerned; but the

important point to them is, that, should there be any such alteration as has been supposed, the coefficient would vary with the thickness of the object-glass employed, and this to a sensible amount.

The question was raised by Professor Klinkerfues, and has led to an animated discussion, in the course of which MM. Hoek, Sohncke, and Ketteler took exception to Klinkerfues' views, but mainly on theoretical grounds, whilst he supported his conclusions by an experiment, first suggested by Boscovich. The instrument used by him was a diagonal transit of 18 inches focal length, containing a column of oil of turpentine 8 inches long, enclosed between parallel glass plates. The theoretical increase of the aberration in his observations would be about 8″, whilst that observed was 7″·1. It was to test this experiment that the Greenwich instrument was designed by the Astronomer Royal, and the result of last year's observations with it is conclusive.

The observations consisted of measures of the zenith distance of *γ Draconis* near the two equinoxes, where aberration produces the greatest effect, but with opposite signs. On comparing the observed places of the star with the tabular places in the *Nautical Almanac*, in computing which the ordinary coefficient is of course adopted, the latitude of the instrument was determined as follows:—

From the Spring observations	=	51° 28′ 34″·4
From the Autumn observations	=	51 28 33·6

agreeing within the limits of error of observation; while, according to the theory of Professor Klinkerfues, the difference should have been nearly 24″. The observations will be repeated this year.

Scintillation of the Stars.

The results of some very interesting observations made by Professor Respighi, of Rome, on the scintillation of the stars, although not strictly belonging to the work of the past year, deserve a record in the Annual Report of this Society. They form the subject of a paper read before the Accademia Pontificia dei Nuovi Lincei, and published in their *Memoirs*. The observations were made in 1868 and 1869. The instrument employed was an equatoreal by Merz, of $4\frac{1}{3}$ inches aperture, provided with a direct-vision prism by Hofmann, having a cylindrical lens between the prism and the eye-glass. The observations were made on stars in every position, of all magnitudes, and under every variety of circumstances with respect to azimuth, altitude, and atmospheric conditions.

When a star near the horizon was viewed by Professor Respighi through the spectroscope, he observed that its spectrum exhibited the characteristic lines of that star, and also broad bands, usually dark, but occasionally bright, which slowly passed

from one end of the spectrum to the other. Professor Respighi noticed especially that the motion of the undulations was from the red end of the spectrum towards the violet end, for the stars in the west; and, on the contrary, from the violet end to the red end, for the stars in the east; while on or near the meridian the movements were more or less irregular. The undulations were always observed with much more distinctness in stars near the horizon than in those at a great elevation.

From a due consideration of the phenomena presented to his view in the course of his observations, Professor Respighi was led to the conclusion that these undulations, taking into account the opposite movements of the stars in the east and west, were caused not so much by any accidental motion of the atmosphere, as by its general movement ascending towards the west or descending towards the east, as the result of the diurnal motion of the earth. "When the luminous rays," he observes, "traverse the lower regions of the atmosphere, where, in consequence of the differences of temperature and of the unequal condensation of aqueous vapour, the atmosphere itself is found in a state of sensible heterogeneity, the condensed or rarefied atmospheric strata would be brought, by the diurnal rotation of the Earth, for the stars in the west first on the red rays, and afterwards on the more refrangible rays as far as the violet; and, on the contrary, for the stars in the east, at first on the violet rays, and finally on the red. The effect of this is, that the corresponding undulations on the spectrum would travel from the red to the violet for the west stars, and from the violet to the red for the east stars, precisely in the same manner as shown by the observations."

The characteristic phenomena observed by Professor Respighi have been given by him as follows:—

1. In ordinary atmospheric conditions the movement of the bands is from red to violet for all stars in the west, while for stars in the east the motion is from violet to red.

2. For stars on or near the meridian, whether north or south of the zenith, the motion generally oscillates backwards and forwards; sometimes the bands are stationary, or traverse only a very limited portion of the spectrum.

3. Near the horizon the movement of the bands is more regular and less rapid, while the contrary effect is seen at greater elevations.

4. When the spectroscope is placed in a position so that the spectrum becomes vertical, the motion of the bands is similar to that where the spectrum is horizontal; but the bands are nearly transversal, and not so well defined to an altitude of 30° above the horizon. For greater altitudes they become gradually more indistinct, often changing into longitudinal bands, and occasionally into mere bright or obscure masses.

5. The dark bands are much more frequent than the bright, the latter occurring only near the horizon.

6. In the case of stars of a low elevation, it not unfrequently happens that, in addition to the regular series of bands, others appear less regular in their motion, of greater inclination, and longitudinal.

7. Under the ordinary atmospheric condition, stars near each other present similar phenomena.

8. When the atmosphere is in an abnormal state, the bands are fainter and less decided in their form and motion.

9. During the prevalence of high wind the bands are very indistinct, and little or no motion is perceptible even when the stars are near the horizon.

10. They are also very indistinct when the images of the stars are blurred.

11. When the motion and form of the bands are regular there is generally tranquil weather.

12. The phenomena of scintillation are always most favourably observed on evenings when the atmosphere is charged with an excess of moisture.

Without following Professor Respighi in his discussion of the probable causes by which scintillation is produced, it will perhaps be sufficient to remark that he considers that his observations prove that its origin must be due to the subtraction of a part of the stellar rays by the unequal refraction of the masses of air through which they are made to pass by the diurnal rotation of the Earth; he therefore is inclined to reject the interference theory of Arago, and also that of Montigny, who described the phenomena as arising from the total reflection of a portion of the rays by strata of air unequally heated.

Distribution of the Fixed Stars in Space.

Mr. Proctor has extended to the stars included in Argelander's charts the principle of isographic charting, which he regards as the most effective means at present available for determining the laws according to which the celestial objects are distributed throughout space. These charts contain, as is known, upwards of 324,000 stars, from the first to the eleventh magnitude (Herschel's scale) inclusive, and they present the whole of the northern heavens and a zone two degrees wide south of the equator. The most prominent feature in the isographic chart, as described by Mr. Proctor, is the marked aggregation of stars along the galactic zone. The aggregation is not, however, by any means uniform. It is not towards the central line of that zone that the stars of the above-named orders are gathered; but there are well-defined streams, patches, and nodules of stars, resembling in general respects the complex region of the Milky Way between *Centaurus* and *Aquila*, as pictured by Sir John Herschel. Mr. Proctor considers that, while this result entirely confirms, on the one hand, the general conclusion of the elder Struve that the Galaxy is a region of condensation for the leading

orders of stars, and not alone or chiefly for stars between the 12th and 20th orders ; it is, on the other hand, not in accordance with Struve's hypothesis of a central plane, towards which stars of all orders are aggregated. Mr. Proctor regards the relatively narrow cross-section of the streams, patches, and nodules, as demonstrative of the existence of real streams, patches, and nodules of stars in space. Moreover, he points out that it is within the same streams, &c. that Sir W. Herschel found the richest distribution of small stars,—down even, in certain instances, to nebulosity not resolvable with Herschel's largest telescopes ; and he hence concludes, that within a certain region of space there coexist stars of all orders of real dimensions, from stars which, at the distance of their proper region, are visible to the naked eye, down to stars so minute and so closely aggregated as to present a nebulous appearance in our most powerful telescopes.

It may, perhaps, be remembered, that in the Supplementary Number of the *Monthly Notices* for 1869, Mr. Proctor presented isographic charts, showing the laws according to which the irresolvable nebulæ are spread over the heavens. He believes that in the outlying streamers of the rich galactic regions in the isographic chart of 324,000 stars, he can recognise a tendency towards those regions of the northern heavens where nebulæ are most abundant. This, of course, would be intelligible, if these nebulæ are in reality not external galaxies, but groups of relatively minute stars, forming part and parcel of our own star-system.

It will be evident that, to establish on a firm basis such theories as these, a more complete and systematic survey of the heavens than has hitherto been attempted should be undertaken. Mr. Proctor advocates the prosecution of such surveys, based on the method of star-gauging, but carried out with telescopes suitably graduated as respects space-penetrating power, and to be eventually extended to the whole of the celestial vault. He considers, that if isographic charts were formed from the gauge-books for the several powers, the comparison of these charts *inter se*, as well as the independent study of each, could not fail to reveal results of the utmost interest and importance.

As a small step on this path, he has begun to gauge the northern heavens with the $4\frac{6}{10}$-inch telescope, No. 3, of the Sheepshanks collection, lent to him by the Society (during the pleasure of the Council) for this purpose.

Motion of Matter projected from the Sun.

In papers which will be found in the *Monthly Notices* for 1870–1871, Mr. Proctor has called attention to evidence suggesting (in his opinion) the existence of disturbances acting vertically with reference to the Sun's globe, and affecting the condition of matter surrounding the Sun. Without actually putting forward the theory that the corona is due to such radial forces,—acting either explosionally or else repulsively without actual explosion,—

he yet considers that such a theory accords better than any other with what is at present known respecting the corona. As evidence in favour of this theory, Mr. Proctor cites the observed great altitude of many eruption prominences (indicative of high velocities of ejection), the greater extension of the inner corona over regions of prominence-activity; the greater extension of the outer corona where the inner is also most extended; the high velocities of certain meteors (which, according to this theory, would be regarded as sun-expelled or star-expelled bodies), such velocities exceeding those due to solar attraction; the chemical constitution of meteorites, their structure, as revealed under the microscope; the radial lines seen in the corona, and other circumstances.

In a later paper (*Monthly Notices*, for December, 1871) Mr. Proctor has discussed the phenomena witnessed by Professor Young on September 7, 1871 (as mentioned elsewhere). He shows that erupted matter could not have traversed the observed space in the observed time, if ejected *in vacuo* from the Sun, unless the velocity of eruption were 260 miles per second, corresponding to a vertical range of 360,000 miles. Since the observed vertical range was but 210,000 miles, he infers that the motion of the hydrogen wisps was excessively retarded by the resistance of the solar atmosphere, and that the actual velocity of eruption was greatly in excess of the above-named amount; and he suggests that denser matter ejected along with (or perhaps through) the glowing hydrogen, would be less retarded, and might retain at least a sufficient velocity to travel to the observed limits of the corona.

Laws of Frequency of Sun-spots.

Messrs. De La Rue, Stewart, and Loewy, have published fresh and very interesting results of their researches into the phenomena of the solar photosphere. The present results relate chiefly to the laws according to which the frequency of Sun-spots attains and descends from the maximum, in different Sun-spot periods. As respects the general law of increase and decrease of spot-frequency, these observers confirm the discovery of Professor Wolf, that the interval of time between a minimum and the next maximum is about one-half as long as the interval between a maximum and the next minimum, the former period being on the average about 3·7 years, the latter about 7·4 years. But as their recognition of this law is based on a much longer and more complete series of observations,— their researches dealing with all Mr. Carrington's observations as well as with the photographic records of the Kew Observatory,—their testimony has a great and independent value. As respects the law of increase and decrease in given spot-periods, their conclusion differs in an important respect from Professor Wolf. The latter appears to consider, that when the spot-frequency has descended rapidly or slowly from a maximum value to the next minimum,

it ascends with corresponding (relative) rapidity or slowness to the next maximum. Messrs. De La Rue, Stewart, and Loewy, consider, on the other hand, that when the spot-frequency has passed rapidly or slowly from a minimum to the next maximum, it descends with corresponding (relative) rapidity or slowness to the next minimum.

The Great Nebula surrounding η Argûs.

Mr. Abbott, of Hobart Town, has invited fresh attention to the subject of the great nebula surrounding *Eta Argûs*. A careful examination of the evidence has led Mr. Lassell to the conclusion that no proof has yet been given of any change in the nebula at all. The Astronomer Royal has also pointed out that Mr. Abbott's observations have not been recorded in a manner which can be regarded as satisfactory. Captain Herschel gives as the result of a careful comparison which he has instituted between Mr. Abbott's drawings and the splendid monograph in Sir John Herschel's *Southern Observations*, that Mr. Abbott appears to have mistaken a low-power view for a small portion of the nebula full of detail. Dr. Gould has compared some observations of the nebula made by him at Cordoba with Sir John Herschel's drawing, and is strongly impressed "with the conviction that the alleged change is altogether imaginary."

Total Eclipses of the Sun, 1872–1900.

So much interest has been taken in all recent total eclipses of the Sun, that it becomes highly important to know the dates when future eclipses of this kind may be expected within the next few years. Those interested in these phenomena are, therefore, much indebted to Mr. Hind for his contribution on this subject, which, it is believed, was first published in the columns of a daily journal. As the results of Mr. Hind's calculations have not appeared in the *Monthly Notices*, it may be useful to future observers to make in this place a more permanent record of a few of the principal facts. It will be seen that during the interval between 1872 and 1900, only one total eclipse of the Sun occurs where the central shadow-path passes over Europe.

Date	The most favourable Locality for Observation.	Greatest Duration of Totality.
		m s
1874 April 16	South Africa	3 37
1875 April 6	Siam	4 6
1876 September 17	South Pacific	1 40
1878 July 29	W. North America	3 6
1882 May 17	Arabia	2 0
1883 May 6	Marquesas Islands	5 15
1885 September 9	New Zealand	2 0
1886 August 29	West Africa	6 21
1887 August 19	Russia	3 40
1889 December 22	Angola, W. Africa	3 34
1893 April 16	Brazil	4 44

The elements of the eclipse visible in North America on July 29, 1878, are given in detail in the *Monthly Notices* for May, 1871.

Chronographic Determinations of Longitude.

The results of one of the most important of chronographic determinations of longitude have lately been published by Mr. G. W. Dean, of the United States Coast Survey, who was intrusted by Professor Pierce, the Superintendent, with the details of the operation. The terminal stations of this remarkable experiment were Cambridge, Massachusetts, and San Francisco, on the Pacific Coast; the distance between them by the telegraphic route being about 3550 miles. Omaha in Nebraska, and Salt Lake City, were chosen as intermediate stations. The observers were chiefly officers attached to the Coast Survey. Professor Winlock, Director of the Harvard Observatory, superintended the longitude operations at Cambridge. The observations of transits and signals were recorded at each station on a chronograph-register. In addition to the ordinary work for longitude, special experiments were made for the purpose of measuring the "transmission-time" of signals sent direct from Cambridge to San Francisco, and *vice versâ*. The total length of the circuit on these occasions, in the double transmission, was about 7200 miles, using thirteen "telegraph-repeaters," or relay-magnets, in the operation.

It is unnecessary to give in this Report the details of the observations and calculations, which, with the formulæ used in the reductions, are fully given in Mr. Dean's paper. The Fellows will, however, have some notion of the satisfactory character of the results in the following brief abstract of the final observed differences of longitude between Cambridge and San Francisco:—

	Difference of Longitude.	Interval of Time of Transmission through 7200 miles of wire.
	h m s	s
Cambridge to San Francisco direct	= 3 25 7·190	0·817
(C to O) + (O to S. L.) + (S. L. to S. F.)	= 3 25 7·194	0·838
(C to O) + (O to S. F.)	= 3 25 7·183	0·819
(C to S. L.) + (S. L. to S. F.)	= 3 25 7·211	0·833

The excellent agreement of the four independent determinations gives a sufficient guarantee for the trustworthiness of the final mean result. By combining the resulting difference of longitude between Cambridge and San Francisco with that between Greenwich and Cambridge, determined by Dr. Gould in 1866, we have one continuous galvanic measurement of an arc of parallel extending over more than eight hours of longitude.

Another important chronographic determination of the differ-

ence of longitude, of which the results have only recently been published, has been made between a temporary astronomical observatory on the Righi-Kulm and the observatories of Zürich and Neufchâtel, by MM. Plantamour, Wolf, and Hirsch. The observations were made during the summer of 1867, as part of a series of chronographic determinations of the difference of longitude between several places in Switzerland, under instructions given by the Geodesic Commission of that country, who, at their first meeting, decided that these determinations should not be confined to the four observatories of Geneva, Neufchâtel, Berne, and Zürich, but that a certain number of astronomical stations, easily accessible, should be included in the plan of operations, determining at the same time the latitude, azimuth, and intensity of gravity at each of the subordinate stations. One of the results of the series, the difference of longitude between Geneva and Neufchâtel, has already been published.

The results of the present determination of the difference of longitude between the station on the Righi and the observatories of Neufchâtel and Zürich, are given in the greatest detail, and every care appears to have been taken in the arrangement and making of the observations, both of the stars for local time and the registration of the signals. Special attention was also given to the determination of the personal equations between the three observers, which were determined from comparisons of transits observed at intervals from 1861 to 1871. The final results are:—

	m s	
Righi, west of Zürich	0 15·839	Diff. of longitude.
Neufchâtel, west of Righi	6 6·528	,,
Neufchâtel, west of Zürich	6 22·367	,,

The velocity of the galvanic current was found to be about 7300 miles in a second.

The difference of longitude has also been lately determined between the observatories of Naples and the Collegio Romano at Rome. The details are given in a joint memoir by Father Secchi and Signor Fergola. The signals were transmitted to and from each observatory, on eleven days, between January 2 and 24, 1869, the observations of the stars being recorded on the chronographs at each station. The results are very satisfactory, giving, after the correction for personal equation, a definitive difference of longitude of $7^{m}\ 6^{s}\cdot247$, the time occupied in the transmission of the galvanic current from one station to the other being $0^{s}\cdot018$.

Tables of Jupiter's Satellites.

Several discussions have lately taken place at the ordinary meetings of the Society respecting the observed inaccuracy of the tabular mean solar times of the eclipses and other phenomena of the satellites of *Jupiter*, computed from Damoiseau's tables,

and published in the *Nautical Almanac*. Although the motions of the satellites are represented by Damoiseau's tables much closer than by the more ancient tables of Delambre, yet a difference of from five to ten minutes is not uncommon between the tabular and observed times of a phenomenon, and occasionally this difference has amounted to more than twenty minutes in transits and occultations of the fourth satellite. The subject is of very great importance, and is one to which the attention of the mathematical astronomer may reasonably be directed at the proper time, but before any new tables can be constructed it will be necessary to accumulate very many more observations of each class of the phenomena, and to compare them with the existing tables. A considerable number of eclipses, &c. have already been observed at various places, especially at the Royal Observatory, Greenwich, since the date of the publication of Damoiseau's tables, but the great majority of them are of the first and second satellites. Of the third satellite the observations are much fewer, and of the fourth they are very rare. They are certainly far too few in number to eliminate the probably large errors of observation, or to sensibly correct the elements adopted by Damoiseau.

In a paper read before the Society at the January meeting, the Astronomer Royal suggests a plan of operation which appears to him to be the only prospect, for very many years to come, of obtaining sufficient observations for the proper construction of new tables. He proposes "that one of our observatories should be permanently devoted to the observation of the phenomena of *Jupiter's* satellites," to be followed up faithfully and systematically. He remarks:—"In late years the observations of the satellites have been greatly neglected. The few observations that have been made of the third and fourth satellites are sufficient to show that the errors of their tables are too large to enable us practically to use these objects for even rude time-determinations, and at the same time are far too rarely determined to enable us to correct the elements of the tables. Of the first satellite there are sufficient observations, possibly also of the second satellite. But it must always be borne in mind that the tabular movements of the satellites cannot be corrected one by one; the necessary relation among their motions, to which I have already alluded, compels us to treat all together, and in combination with one of the most delicate theories of science."

The observed discordances in the times of disappearance and reappearance of the satellites, in and from the shadow of *Jupiter*, noticed in the observations of the same phenomenon made by different observers, depend principally upon the aperture of the telescope employed, but not always. There must, therefore, be some uncertainty in these observations, which can only be eliminated by a large number of comparisons of the observed and tabular times. Delambre, writing in 1817, remarks:—"Pour le quatrième satellite, on s'attend bien que les erreurs seront beaucoup plus fortes que le troisième, et les comparaisons moins

nombreuse. Je trouve entre les observations d'une même éclipse des différences qui vont à 7, 8, 10, 12, et 14 minutes : et ce qu'il y a d'étonnant, c'est que ces discordances énormes ne sont pas toutes vers les limites. J'en trouve une qui est de $29^m\ 15^s$." The number of eclipses of the third and fourth satellites used by Delambre in the construction of his tables were 590 and 334.

The Astronomer Royal believes that any observer undertaking the systematic observation of these phenomena would find "that the mere observations, in their beauty and the incessant variation of their character, would be found very interesting, but that the highest interest would be felt in connecting them with their appropriate theory, and in making the preparations for that numerical work by which each observation would be made to bear its part in the correction of elements and in the ultimate test of the theory."

If one of our existing public or private observatories, furnished with a good equatoreal, would volunteer for this service and carry it out faithfully, the much-wanted accumulation of data would in due time be obtained. Occasional observations at convenient hours are not all that is required; but it should be considered by the observer as a strict part of his duty, that he should record, when practicable, every eclipse, transit, or occultation, and under favourable circumstances, the ingress and egress of the shadows, especially of the third and fourth satellites. Whoever will undertake to make these observations and publish the results in a regular manner, cannot fail to be remembered in the future history of Astronomy, as having made a most valuable contribution to the fundamental data of an interesting and important branch of our science.*

Preparations for the Transit of Venus of 1874.

It is a great pleasure to the Council to be able to report that it has been determined to make photo-heliographic observations of the forthcoming transit of *Venus* in 1874. At the Annual Meeting of the Board of Visitors of the Royal Observatory, in June last, it was resolved that immediate application be made to the Lords Commissioners of Her Majesty's Treasury for a grant of money, in order that a series of photographic records of the transit may be made at the five stations,—Woahoo, Kerguelen's and Rodriguez Islands, Auckland in New Zealand, and Alexandria. The Government, with that liberality which it has shown on other occasions in favour of astronomy, at once granted a sum, not exceeding 5000*l.*, to defray the expenses of construct-

* Since writing the above we are informed that Lord Lindsay intends to undertake the systematic observation of the phenomena of *Jupiter's* satellites, at his observatory, Dunecht House, Aberdeen, as soon as the instruments, now being constructed for him, are mounted. He expects to be ready to commence regular observations in about a year from this date. The observatory is situated, however, in too high a latitude for successful observations when *Jupiter* has a large south declination.

ing the necessary instruments. Instructions have therefore been given to Mr. Dallmeyer to construct, under the able supervision of Mr. De La Rue,* five photo-heliographs, of a similar design to that made by him for the Wilna Observatory, and which has produced Sun-pictures of extreme sharpness of definition without sensible distortion. With instruments of this refined class we can look forward to the photographic section of the observations of the transit of *Venus* with great hopes of success. It would have been a great misfortune for science had the expeditions been allowed to leave England unprovided with the means for photographing the different phases of the phenomenon as the planet traverses the Sun's disk from ingress to egress.

It may be remarked, also, that, under the control of the Astronomer Royal, satisfactory progress has been made with the preparation of the instruments and clocks, with which it is intended to furnish each of the five stations, to be used in the direct observation of the ingress and egress, and for the determination of the longitudes and latitudes. Each station will be furnished with three telescopes, a transit-instrument, an altazimuth, and an equatoreal of 6 inches aperture, with their accompanying clocks. For each instrument a separate observing-hut is or will be constructed. All the new instruments have been made by Messrs. Troughton and Simms, and the clocks by Messrs. E. Dent and Co. The telescopes will be supplied with the prismatic eye-piece contrived by the Astronomer Royal for the correction of atmospheric dispersion at low altitudes where some of the observations must necessarily be made. A few of the observing-huts have been put together in the grounds of the Royal Observatory, and a transit-instrument and altazimuth *in situ* were exhibited at the annual visitation in June last. For the convenience of several officers of the Royal Artillery who are expected to form part of the expedition, and to afford them an opportunity for making a practical acquaintance with the instruments, a temporary observatory has been fitted up at Woolwich, near to the officers' quarters.

The Transits of Venus in 2004 *and* 2012.

While the attention of astronomers of various nations is occupied by the necessary preliminary work relating to the transits of *Venus* of 1874 and 1882, Mr. Hind has been making a very interesting calculation for the purpose of showing under what conditions the pair of transits in the beginning of the twenty-first century will take place. M. Le Verrier's Tables of the Sun and *Venus* represent so closely the motions of the

* Besides these five instruments, three more are being constructed of exactly the same form and dimensions; two for the Russian Government and one for Mr. De La Rue, so that there will be eight instruments as alike as possible available for the transit of *Venus*.

Earth and *Venus* in their orbits, that there can be little reason to doubt that the Tables will be as sensibly perfect in 2004 as they are at the present time. Hence, Mr. Hind has every confidence in the results which have been calculated by himself, with every precaution to avoid error. The following is a short abstract of the results, which were first published in the *Proceedings* of the Royal Society.

Transit of 2004.

Greenwich Mean Time of Conjunction in Right Ascension June $7^d\ 20^h\ 51^m\ 28^s{\cdot}8$.

For the centre of the Earth.

	d	h	m	s		°
First external contact	June 7	17	3	43	at	115·0
First internal contact	,,	17	22	35	,,	118·0
Second internal contact	,,	23	5	40	,,	214·6
Second external contact	,,	23	24	32	,,	218·5

The angles are reckoned from N. towards E. for the direct image.

At Greenwich the entire transit will be visible.

Transit of 2012.

Greenwich Mean Time of Conjunction in Right Ascension = June $5^d\ 13^h\ 4^m\ 44^s{\cdot}3$.

For the centre of the Earth.

	d	h	m	s		°
First external contact	June 5	10	22	11	at	40·3
First internal contact	,,	10	39	56	,,	37·8
Second internal contact	,,	16	42	6	,,	293·1
Second external contact	,,	17	0	0	,,	290·5

At Greenwich the egress only will be visible, the Sun rising at $15^h\ 46^m$.

The Great Melbourne Telescope.

After the many unexpected difficulties attending the erection and preliminary employment of the Great Melbourne Telescope, it is gratifying to hear that these hindrances—not uncommon, however, in all new instruments when the construction is somewhat of a novel character—have been entirely surmounted, and that the telescope is now in a proper condition for regular and successful observation. The Observatory of Melbourne may therefore be congratulated on having so magnificent a telescope added to its ordinary instruments. An extensive correspondence, containing a complete history of its construction, from its conception to its erection in its appointed home, has been pub-

lished by the Council of the Royal Society. This correspondence includes, among other valuable information, the opinions of persons who are practically acquainted with the use and peculiarities of large astronomical instruments; opinions which cannot fail to be especially valuable to those who may find themselves engaged at some future time on a work of this kind. A great difficulty, and at one time one of great apprehension, arose from the unexpected tarnishing of one of the specula, and it was feared that the repolishing could not be effectively performed at Melbourne. These fears were, however, groundless; for the speculum has not only been repolished, but it has been done to the satisfaction of Mr. Ellery, who speaks of its performance as "highly satisfactory." In his last Report he thus alludes to this instrument:—"Further experience with the great telescope, and of the conditions which affect its performance, have very much enhanced our opinion of it: and the drawings and other results obtained unmistakably show that excellent work can be done with it. On really favourable occasions the performance, even with very high powers, is exceedingly good. It is evident, however, that a telescope of such large dimensions requires a very long practice before it can be fairly or successfully used. The mechanical arrangements are all in perfect order; and the moving and setting the telescope from one object to another is performed almost as quickly and easily as with a five-feet equatoreal. The clock has worked well and with great regularity from the first."

Sir John Herschel's "General History of Double Stars."

It is with great satisfaction and pleasure that the Council inform the Fellows of the Society of a valuable bequest which has been made to it by Sir John Herschel, namely, the gift of the whole of the papers connected with his laborious and most valuable "General History of Double Stars."

Many of the Fellows are probably aware that this great work had occupied a considerable portion of his time and attention for a great many years, and our only regret is that he did not live long enough to complete it, and to see the fruits of his labours. One important portion of it is, however, so nearly complete, that the Council have accepted the recommendation of the Committee appointed to examine and report upon the papers, to print this section entire. The portion of the work referred to is a Catalogue, in order of right ascension, of all the double stars of which Sir John Herschel, in the course of his researches, found observations, amounting in number to about 10,300. For the whole of these stars the approximate right ascensions and north polar distances are supplied for the epoch 1830, and the greater number of the annual precessions for that epoch are filled in. Under the direction of the Committee this great catalogue will be completed and printed; and with regard to the uncompleted portion of the

"General History," which consists of several thousand detached papers, giving the details of the observations of each separate star, for those which Sir John had time to extract from the various catalogues or other authorities which came under his review, the Council have taken measures for their safe custody, and for their being put into such a state as will make them easy for reference by any astronomers who may desire to consult them.

The Fellows will doubtless feel greatly gratified by this proof of the affectionate regard which Sir John Herschel, throughout his long life, entertained for this Society, of which he was one of the chief originators and supporters, and they cannot do otherwise than prize very highly the dedication to it of this, the most laborious probably, if not the greatest, of his works.

The Constant of Precession.

M. Nyrén, of Pulkowa, has made a new and careful determination of the constant of precession, based on the right ascensions contained in Weisse's-Bessel Catalogue of Stars situated between $-15°$ and $+15°$ declination, and in Schejellerup's Catalogue of telescopic stars, also situated between the same degrees of declination. M. Nyrén considers that, although the places given in these catalogues are not very exact, most of the stars having been observed only once, yet he believes that, in the mean results, any uncertainty arising on this account will be balanced by the large number of available comparisons, amounting in round numbers to about 5300. The final results for the general precession obtained by M. Nyrén, reduced to the epoch 1800, is $50''{\cdot}1882$, differing but slightly from that previously determined.

Trettenero's Catalogue of 1425 *Stars.*

Volume XV. of the *Memoirs* of the Istituto Veneto di Scienze, Lettere, ed Arti, lately published, contains a Catalogue of the mean right ascensions and declinations of 1425 stars, observed by the late Professor Trettenero with the meridian-circle, at the Observatory of Padua, between April 18, 1861, and February 7, 1863. The stars are confined to a limited zone, extending from the equator to 3° South declination. The observations were reduced by Signor Lorenzoni, successor to Professor Trettenero, whose premature decease took place in May 1863. Professor Santini has affixed a short preface to the Catalogue. Most of the resulting right ascensions and declinations depend upon two observations in both elements; sometimes on as many as four or five, but frequently they depend on one observation only. All the stars appear to be included in the first Catalogue of Weisse's Bessel, and comparisons of the corresponding places of each star are given; the discordances between the two Catalogues being in most cases of no great amount. The series of catalogues of small

stars emanating from the Observatory of Padua, of which the present one is the fifth, is a very valuable contribution to the libraries of our observatories.

Cape Observations.

The first volume of Observations made with the Transit-Circle at the Royal Observatory, Cape of Good Hope, under the direction of Sir Thomas Maclear, has been published during the past year. It contains the separate results for mean R.A. and N.P.D. of stars reduced to January 1, 1856, and observed during that year; a catalogue of the concluded mean R.A. and N.P.D. of the same stars; meridional observations of the Sun, Moon, and planets in 1856; equatorial observations of Encke's Comet in 1855; and detailed tables of the clock and instrumental errors. The second volume is in the press, and will contain the observations made in 1857 and 1858.

We are indebted to Mr. Stone, under whose superintendence these volumes have been prepared for the press, for this first instalment towards the materials for a new standard Catalogue of Southern Stars. He is wisely devoting his attention to the reduction of the meridional observations, which had been yearly accumulating since the erection of the Transit-Circle, before commencing any very elaborate scheme of observation of the small Southern Stars, which he will probably in due time undertake. A considerable number of observations for special purposes have, however, been made during the past year, both with the Transit-Circle and Equatoreal, a reference to which is made in a preceding section of this Report. Mr. Stone has been in communication with the Government with the object of adding a portable alta-zimuth to the instruments of the Observatory and of improving the mounting of the Equatoreal, which could be made a first-rate instrument of its class, if firmly remounted with all the modern improvements. Mr. Stone is also anxious to have a complete set of magnetical instruments of a similar pattern to those in use at the Kew Observatory.

Pulkowa Observations.

The new volume of the *Observations de Pulkowa*, the third of the series, contains a very elaborate discussion, by M. Wagner, of the resulting mean right ascensions of the principal stars observed with the transit-instrument between the years 1842 and 1852. The observations employed are published in the two preceding volumes of the series. A large portion of the work consists of what may be termed a combined "ledger," exhibiting the separate results for each star observed during the interval, reduced to the general epoch 1845·0, and arranged in groups according to the four positions in which the instrument was placed during the observations. The means of the groups have been taken separately for the four positions, and corresponding corrections have been applied in every case when the star has not been completely

observed, or when the observations made in one position have not been sufficiently numerous. The mean right ascensions deduced from the four groups are in general very accordant with each other, and are an excellent testimony to the care taken by M. Wagner, in his system of calculation. The discordances exhibited, however, between the separate observations are about the same as those found in long groups of resulting right ascensions at other observatories. The second portion of the volume contains a detailed description of the observations made with the Transit-instrument placed in the prime-vertical, and of the methods employed in the instrumental adjustments and in the reduction of the observations. These are divided into three series, of which the first was made by Professor W. Struve in 1840–1842, for the determination of the constant of aberration; the second, by Professor Struve in 1840–1845, and by M. O. Struve in 1858–1859, for the determination of the constant of nutation; while the third series consists of observations made by M. Oom in 1861–1863, who was then attached to the Observatory of Pulkowa.

Papers read before the Society from February 1871, *to February* 1872.

1871.

Mar. 10. Report of the Augusta Eclipse Expedition. Prof. W. G. Adams.
Note on the Corona. Mr. Proctor.
On the Distribution of 326,000 Stars in Argelander's Charts. Mr. Proctor.
On the Colour of the Moon during the late Eclipse. Mr. Proctor.
On the Zodiacal Light. Mr. Ranyard.
Observations of the Solar Eclipse at Greenwich. Mr. Airy.
Erratum in Observations of Solar Eclipse, July 18, 1860. Mr. Airy.
Note on the Misuse of a Common Symbol. Capt. Noble.
Occultation of *η Cancri*, March 3, 1871. Capt. Noble.
Occultation of *Uranus*, March 2, 1871. Capt. Noble.
On a Contrivance for protecting the Observer when a Reflecting Telescope is used in the open air. Mr. Browning.

April 14. Remarkable Appearance during Solar Eclipse, Dec. 1870. Capt. Hardy.
On the Zodiacal Light. Rev. A. Jevons.
On Spectroscope Observations. M. Chacornac.
Observations of *Amalthea* (III). Prof. Luther.
Calculations to obtain the exact Distance of the Sun, Moon, &c., from the Earth. Mr. Dingle.
Observations and Elements of Winnecke's Comet. Mr. Hind.
On the Orbits of *ζ Herculis* and *ζ Cancri*. Mr. Plummer.

May 12. *η Argûs* and the surrounding Nebula. Mr. Abbott.
Occultation of *Uranus*, March 2, 1871. Mr. Maguire.
Note on *η Argûs*. Mr. Tebbutt, jun.
On a Free Regulator Clock. Mr. Kincaid.
Observations of *Mars*. Mr. Joynson.
On a Double Automatic Spectroscope. Mr. Proctor.
On the Total Solar Eclipse, 1878, July 29. Mr. Hind.
Ephemeris of the Periodical Comet of 1867. Mr. Hind.
On the First Comet of 1867. Mr. Hind.
On De Vico's Comet of Short Period. Mr. Hind.
On the Reappearance of Encke's Comet, 1871. Mr. Hind.
Elements and Ephemeris of Comet I. 1871. Mr. Hind.
Une nouvelle Combinaison Spectroscopique. Father Secchi.
On the use of Compound Prisms. Mr. Browning.

On the Changes of Colour in the Equatorial Belt of *Jupiter*. Mr. Browning.

June 9. On the Initial Velocities of the Planets. Mr. Abbatt.

On Auroral and Faint Spectra under small dispersion. Prof. C. P. Smyth.

On the Physical Changes in *Jupiter*. Mr. Ranyard.

On the expression of Delaunay's l, g, h, in terms of finally adopted constants. Prof. Cayley.

Observations of Winnecke's Comet. Rev. S. Perry.

On the Total Solar Eclipse of Dec. 1871, on the Australian Continent. Mr. Hind.

Occultation of 80 *Virginis* by the Moon, May 30, 1871. Capt. Noble.

Nov. 10. On the Precession of the Equinoxes. Mr. Doyley.

Observations of Solar Spots. Mr. Bew.

On supposed Changes in Nebula round η *Argûs*. Mr. Lassell.

Errors in Logarithmic Tables. Mr. Wackerbarth.

Observations of *Saturn*, *Mars*, &c. Rev. J. Spear.

On the Zodiacal Light. Capt. Tupman.

Warning to Spectroscopic Observers. Mr. Drach.

Observations of Encke's Comet. Mr. Airy.

R.A. and N.P.D. of Encke's Comet. Mr. Airy.

Sur la variation de la pesanteur dans les provinces occidentales de l'Empire Russe. M. Sawitsch.

Occultations of Stars by the Moon. Capt. Noble.

Note on the Inferior Conjunction of *Venus*. Capt. Noble.

On the Construction of the Heavens. Mr. Proctor.

Nebuleuses découvertes et observées à Marseille. M. Stéphan.

Dec. 8. Lunar Occultations and Eclipses of *Jupiter's* Satellites. Mr. Tebbutt.

Reply to Queries respecting Observations of η *Argûs*. Mr. Abbott.

On the Spectrum of Hydrogen at Low Pressure. Mr. Seabroke.

On Encke's Comet. Mr. Hollis.

On the Geodesic Lines on an Ellipsoid. Prof. Cayley.

Note on an Universal Equatoreal. Mr. Browning.

Occultation of ϵ *Capricorni* by the Moon. Capt. Noble.

Eclipse of *Jupiter's* Third Satellite, Dec. 6, 1871. Capt. Noble.

Note on the November Meteors. Capt. Noble.

Note on the Floor of *Plato*. Mr. Birt.

On the Motion of Matter as projected from the Sun. Mr. Proctor.

On Mr. Abbott's imagined Discovery of Changes in *Argo* Nebula. Mr. Proctor.

Note on a special Point in the Determination of the

Moon's Orbit from Meridional Observations of the Moon. Mr. Airy.
Elements of Minor Planet (116). Dr. R. Luther.
Formules pour le Calcul des Orbites des Etoiles doubles. Dr. De Gasparis.
Observations, Elements, and Ephemeris of Tempel's Comet. Mr. Hind.
Elements of Tuttle's Comet for the Southern Hemisphere. Mr. Hind.
Occultation of *Vesta* by the Moon, 1871, Dec. 30. Mr. Hind.

1872.
Jan. 12. On the Variable Star S *Orionis*. Rev. T. W. Webb.
On the Identity of the Triple Star H. i. 13. Mr. Hunt.
Remarks on the Planet *Jupiter*. Mr. Lassell.
A Suggestion on the use of Chronometers. Mr. Gill.
Occultation of *Vesta*, Dec. 30, 1871. Mr. Talmage.
Note on Encke's Comet. Rev. H. C. Key.
Proposed Devotion of a Special Observatory to the Observation of *Jupiter's* Satellites. Mr. Airy.
Observations of Occultations of Stars by the Moon, and Phenomena of *Jupiter's* Satellites. Mr. Airy.
On the Transit of *Mercury*, 12th Nov. 1782, observed by J. Pennington. Rev. A. Freeman.

List of Public Institutions and of Persons who have contributed to the Society's Library, &c. since the last Anniversary.

Her Majesty's Government.
Her Majesty's Government in Victoria.
The Lords Commissioners of the Admiralty.
Her Majesty's Secretary of State for India.
Her Majesty's Government, N. S. Wales.
Royal Society of London.
Royal Society of Edinburgh.
Royal Asiatic Society.
Royal Geographical Society.
Royal Institution.
Royal United Service Institution.
Royal Society, N. S. Wales.
Royal Society, Tasmania.
Royal Society, Victoria.
Geological Society.
Photographic Society.
Society of Arts.
Zoological Society.

British Meteorological Society.
The Meteorological Office.
The Board of Trade.
British Association.
Art-Union of London.
Institute of Actuaries.
British Horological Institute.
London Institution.
The Committee of Civil Engineers.
Literary and Philosophical Society, Leeds.
Literary and Philosophical Society, Liverpool.
Literary and Philosophical Society, Manchester.
Marine Committee, Liverpool.
The Observing Astronomical Society.
Council of the City of Manchester.
Yorkshire Geological and Polytechnic Society.
Radcliffe Trustees.
National Observatory, Paris.
Imperial Observatory, Vienna.
Imperial Observatory, St. Petersburg.
Royal Observatory, Munich.
Royal Observatory, Brussels.
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Royal Observatory, Madrid.
Observatory, Berne.
Observatory, San Fernando.
Observatory, Collegio Romano.
Observatory, Zurich.
Observatory, Palermo.
Observatory, Leyden.
Observatory, Sydney.
United States Naval Observatory.
L'Académie des Sciences de l'Institut de France.
Depôt Général de la Marine.
Imperial Academy of Sciences, Vienna.
Imperial Academy of Sciences, St. Petersburg.
Royal Academy of Sciences, Berlin.
Royal Academy of Sciences, Göttingen.
Royal Academy of Sciences, Munich.
Royal Academy of Sciences, Brussels.
Royal Academy of Sciences, Turin.
Hungarian Academy of Sciences, Kasan.
Royal Academy of Sciences, Amsterdam.
Royal Institute of Lombardy.
Royal Society, Copenhagen.
Royal Society, Leipsig.
Astronomische Gesellschaft, Leipsig.
Society of Sciences, Cherbourg.

Academy of Sciences, Batavia.
Physical Society, Berlin.
Academy of Sciences, Bologna.
Royal Society, Upsala.
The University, Upsala.
The Society, Geneva.
United States Government.
United States Naval Department.
United States Bureau of Navigation.
American Philosophical Society.
American Association for the Advancement of Science.
American Academy of Natural Sciences.
Connecticut Academy of Arts and Sciences.
Smithsonian Institution.
George Town College.
Franklin Institute.
Canadian Institute.
Editor of the Athenæum.
Editor of the Student.
Editor of the Quarterly Journal of Science.
Editor of Nature.
Editor of the English Mechanic.
Editors of Silliman's Journal.
Editor of the Revue Scientifique.

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Col. Walker.
Prof. Weiss.
Mr. J. Williams.
Dr. R. Wolf.
Prof. C. A. Young.

ADDRESS

Delivered by the President, William Lassell, Esq., on presenting the Gold Medal of the Society to Signor Schiaparelli.

You will have learned from the Report just read, that your Council have awarded the Gold Medal this year to Signor Schiaparelli; and I regret to have to inform you that we shall be deprived of the pleasure of presenting it to him in person; as by a letter received from him a few days ago, I learn that his duties of Professor and Director of the Observatory at Milan will prevent his being able to undertake so long a journey.

The first notice I find of Signor Schiaparelli's labours is his discovery of the minor planet *Hesperia*, at the Observatory of Milan, on the 29th of April, 1861, an indication that, besides his mathematical attainments in Theoretical Astronomy, he possesses industry and practical skill as an observer.

In the *Astronomische Nachrichten* of 13th August, 1864 (No. 1487), is a purely mathematical paper by him, entitled, "Théorèmes sur le mouvement de plusieurs corps qui s'attirent mutuellement dans l'espace." Of this paper, not bearing immediately upon those labours of Signor Schiaparelli which have more especially called forth the award, I will only express the opinion of a friend of high mathematical attainments, who characterizes it "as an elegant and probably original contribution to the theory of the orbits of bodies moving freely in space, and acted on only by their mutual attractions."

I come now to give some account of Signor Schiaparelli's principal discovery of the law of identity of meteors and comets, and of the observations and reflections which led him to that result, as contained in a series of letters to Father Secchi in the year 1866.

It appears from these, that Signor Schiaparelli's study of this subject received a great impulse from his own observation of the meteors which fell on the nights of the 9th, 10th, and 11th of August, 1866. He states that he was then confirmed in the opinion expressed three years before, that, of the meteors which usually fall on those nights, a great number are distinguished by

their starting nearly all from one point. And, from the spasmodic fall of these meteors—more sometimes falling in one minute than in the next quarter of an hour—he inferred that their distribution in space must be very unequal. He also observed that those stars proceeding from one point were all of a fine yellow colour, and left behind them a fugitive but very sensible track; whilst the other meteors, proceeding from various points, offered every variety of colour and form. Hence he concludes that the meteors form a number of rings, and become visible when the Earth traverses their orbit, as if shooting forth from one point in the sky. And he remarks that the observations of M. Coulvier-Gravier, and Professor Heis, and of our own countrymen, Professor Herschel and Mr. Greg, have shown that these radial points occur in every quarter of the heavens: therefore these rings or orbits must possess every possible degree of inclination to the ecliptic.

He then proceeds to inquire how such a mass of cosmical matter could become accumulated in the Solar System. This system seems to consist of two classes—the Planets, characterised by but little excentricity of orbit, slight variation in the plane of the orbit, exclusion of retrograde motion, and a tendency to take the form of a sphere (deviating from it only so much as is necessary to preserve the equilibrium of the body)—these characteristics applying also to the secondary systems, with the exception of the satellites of *Uranus*. The second class consists of cometary bodies, which are under no law as to the planes of their orbits, or the direction of their motions. The point most remarkable about them is the extreme elongation of their orbits, most of which are described in stellar space; which seems to show that they did not form part of our system when that was first constituted, but are wandering nebulæ picked up by our Sun.

Signor Schiaparelli further observes that the velocity of the Solar System through space has been shown by Otto Struve and Airy to be somewhat similar to that of the planets round the Sun. Now if a nebulous body or comet in motion were to come within the action of the Sun, it would go round the Sun at such an immense distance from us, that it would remain invisible. Two circumstances might bring it within our range of vision—first, if the comet met the Sun in almost a direct line; and secondly, if it were travelling in a direction parallel to the Sun's motion.

If we suppose a cloud of cosmical matter formed of particles so minute and so widely separated, as to possess scarcely any mutual attraction, to be brought within the power of the Sun's influence, each particle would pursue an elliptic orbit of its own. Those particles which differed most in the *planes* of their orbits, would however possess *nodes in common*, and, in consequence, the particles as they approached the Sun would necessarily approach each other, and when separating again, after passing the node, would at their perihelion passage be still very much nearer than they were when brought first within the Sun's attraction. Those particles which, lying in the same plane, pre-

sented a wide angle with respect to the Sun, would form *ellipses*, the planes of which would be identical; though the positions of the major axes would diverge: and, as a result, the particles at their perihelion would pass in nearly the same orbit, but at different velocities, the originally foremost particle being overtaken by those behind it. Again, those particles which, being in the same *plane*, were also in the same *line with regard to the Sun*—their separation consisting in the variation of their distance from the Sun—would form *ellipses in the same plane*, and having a major axis in the same direction, but of different lengths,—the orbit of the particle *nearest* the Sun being described *within* that of the furthest particle, the result of which would be a difference of speed, and an ever-widening distribution of the particles along the whole of the orbit. This reasoning is illustrated, in the second letter to Father Secchi, by a series of diagrams and figures; and then Signor Schiaparelli proceeds to give a recapitulation or summary of his principal propositions thus:—Celestial matter may be divided into the following classes, 1st, fixed stars; 2nd, agglomerations of small stars (resolvable nebulæ); 3rd, smaller bodies invisible except when approaching the Sun (comets); 4th, small particles composing a cosmical cloud. This last class probably occupies a large portion of the celestial spaces, and the motion of these dust-clouds may be similar to that of the fixed stars. When attracted by the Sun they are not visible unless they receive an orbit which is an elongated conic section.

Whatever may have been the original form of the cloud, it cannot penetrate far into our system without assuming the form of an elongated cylinder passing gradually into a stream of particles. The number of such streams seems to be very great. The particles are so scattered that their orbits may cross each other without interruption and may possibly be always changing like the beds of rivers. The stream, after passing its perihelion, will be more diffuse than before; and, when passing a planet may be so violently affected as to separate or break up and even some particles may assume quite a new orbit and become independent meteors.

Thus meteors and other celestial phenomena of like nature, which a century ago were regarded as atmospheric phenomena —which La Place and Olbers ventured to think came from the Moon, and which were afterwards raised to the dignity of being members of the planetary system—are now proved to belong to the *stellar regions*, and to be *in truth—falling stars*. They have the same relation to comets as the asteroids have to the planets; in both cases their small size is made up by their greater number.

Lastly, we may presume that it is certain that falling stars, meteors, and aerolites, differ in size only and not in composition; therefore we may presume that they are an example of what the universe is composed of. As in them we find no elements foreign to those of the Earth, we may infer the similarity of composition

of all the universe—a fact already suggested by the revelations of the spectroscope.

Signor Schiaparelli further pursues the subject in another and later paper, published in No. 1629 of the *Astronomische Nachrichten*, entitled, "Sur la Relation qui existe entre les Comètes et les étoiles filantes." In this communication he refers to the letters to Father Secchi above referred to, in which he had endeavoured to bring together all the arguments in favour of the opinion of an analogy between the mysterious bodies known as shooting stars and comets.

Signor Schiaparelli, in this paper, proceeds to state, that he is prepared to afford to this analogy a large amount of probability, since there is no doubt that certain comets, if not all, furnish the numerous meteors which traverse the celestial spaces. In proof of this, Signor Schiaparelli quotes from a paper of Professor Erman, in which he has pointed out the method of obtaining a complete knowledge of the orbit described by a system of shooting stars, when the apparent position of the point of radiation and the velocity through space of the meteors is known.

Assuming from the necessity of the case that the orbit of the August meteors must be an elongated conic section, Signor Schiaparelli employs the method of Erman to calculate the parabolic orbit of those bodies; taking right ascension 44° and north declination 56° for the position of the point of divergence, according to the observations made in 1863 by Professor A. S. Herschel. And he proceeds to give the following elements, assuming the maximum of the display of 1866 to be August 10th, 18 hours. Comparing these elements of the orbit of the August meteors with those of the orbit of Comet II. 1862, calculated by Dr. Oppolzer, he exhibits the following remarkable coincidence in each element:—

	Elements of the Orbit of the August Meteors.	Elements of the Orbit of Comet II. 1862.
Perihelion Passage	23 July, 1862	22·9 August, 1862
Longitude of Perihelion	° ′ 343 28	° ′ 344 41
Ascending Node	138 16	137 27
Inclination	64 3	66 25
Perihelion Distance	0·9643	0·9626
Revolution Period	105? years	123·4 years
Motion	Retrograde.	Retrograde.

Although the time of revolution of the August meteors is still doubtful, Signor Schiaparelli, on reference to the catalogues of Biot and Quetelet, deduces a hypothetic period of 105 years, which introduces but small changes in the elements—very inferior to the uncertainty of some of the data on which this determination is built.

In the letters above referred to, Signor Schiaparelli had given an orbit for the meteors of November, assuming the point of radiation as determined in America to be γ *Leonis*. But later observa-

tions made with much care in England have shown that this position is erroneous by several degrees; so that that orbit can only be termed a very rough approximation. Assuming, then, that the point of radiation is longitude 143° 12′ and latitude 10° 16′ north—that the maximum of the shower was Nov. 13th, 11h. G.M.T.—and that the period of revolution is 33¼ years, according to Professor Newton—Signor Schiaparelli computed the following elements of the meteoric orbit, which he compared with those of the orbit of Comet I., 1866, calculated by Dr. Oppolzer.

	Elements of the Orbit of the November Meteors.	Elements of the Orbit of Comet I. 1866.
Perihelion Passage	Nov. 10·092, 1866.	Jan. 11·160, 1866.
Longitude of the Perihelion	56° 25′·9	60° 28′
Ascending Node	231 28·2	231 26·1
Inclination	17 44·5	17 18·1
Perihelion Distance	0·9873	0·9765
Eccentricity	0·9046	0·9054
Semi-axis Major	10·340	10·324
Revolution Period	33·250 years	33·176 years.
Motion	Retrograde	Retrograde.

The assumed position of the point of radiation of the meteors is the mean of 15 determinations obtained by Professor A. S. Herschel, and given in the *Monthly Notices* of our Society, vol. xxvii. page 19. If this point be advanced 2 degrees in longitude, and 145° be taken in lieu of 143°, the difference of 4 degrees in the place of the longitude of perihelion in the above elements will disappear.

Signor Schiaparelli then concludes his memoir in these remarkable words: "These approximations need no comment—must we regard these falling stars as swarms of small comets, or rather as the product of the dissolution of so many great comets? I dare make no reply to such a question."

In venturing to offer a word or two of comment on this very imperfect *résumé* of the labours of Signor Schiaparelli, it appears to me that we can scarcely speak of them too highly, or overrate their importance. Granting that his hypotheses are correct,—of which indeed there seems to be a very high probability, some of the most difficult questions in the contemplation of the constitution of the universe seem at once, and, as it were *per saltum*, to be solved. To have placed before our view so clear a history of those mysterious bodies—nebulæ, comets, and aerolites, and their several and intimate relations pointed out—is an advancement of Astronomical Science I at least individually had not ventured to anticipate. And a collateral advantage resulting from this splendid discovery, is the encouragement given to the careful and diligent observation of phenomena, even when the prospect of a fruitful result is by no means apparent. Had it not been for the patient, systematic, and intelligent observations of Professor Heis,

M. Coulvier-Gravier, Mr. Greg, and Professor Herschel, Signor Schiaparelli would have wanted many valuable data required in his investigations.

I may finally remark, that an important confirmation of Signor Schiaparelli's conclusions appears in a valuable paper of Professor Adams, in our *Monthly Notices*, vol. xxvii. p. 247, in which from somewhat different data, including some observations of his own, he calculates elliptic elements of the November meteors generally very accordant with those above given.

The President then delivered the Medal to the Foreign Secretary on behalf of Signor Schiaparelli, addressing him in the following terms :—

Colonel Strange, — I have the pleasure to present to you the Gold Medal of the Society, which please to receive on behalf of Signor Schiaparelli, and transmit it to him with our best wishes that he may enjoy a long life of successful research and discovery.

The Meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected:—

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